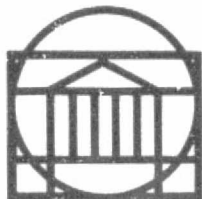


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RESEARCH LABORATORIES FOR THE ENGINEERING SCIENCES



SCHOOL OF ENGINEERING AND APPLIED SCIENCE

UNIVERSITY OF VIRGINIA

Charlottesville, Virginia 22901

A Final Report

DEMAND MODELLING OF PASSENGER AIR TRAVEL

An Analysis and Extension

VOLUME II
Technical Report

Submitted to:

NASA Scientific and Technical Information Facility
P. O. Box 8757
Baltimore/Washington International Airport
Baltimore, Maryland 21240

Submitted by:

I. D. Jacobson
Associate Professor

Report No. UVA/528148/MAE78/101

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ACKNOWLEDGEMENT

The author wishes to thank Messrs. Joseph Scala, Virender Jain, Ralph Stone, A. Robert Kuhlthau, for their many contributions to this work.

INTRODUCTION

Volume II represents the technical aspects of the work which is summarized in Volume I of this report. The purpose of this study is to evaluate previous intercity travel demand models in terms of their ability to predict air travel in a useful way, evaluate the need for disaggregation in the approach to demand modelling and determine the viability of incorporating non-conventional factors (i.e. non-econometric, such as time and cost) in travel demand forecasting models. In essence, the goal is to identify a set of variables which can be used in a predictive way to determine the need for air transportation where none currently exists and the effect of changes in system characteristics on attracting latent demand. The investigation of existing models is carried out in order to provide insight into their strong points and shortcomings. Much of the existing behavioral research in travel demand is incorporated to allow the inclusion of non-economic factors, such as convenience. The type of model arrived at is characterized as a market segmentation model. This is a consequence of the strengths of disaggregation and its natural evolution to a usable aggregate formulation. The need for this approach both pedagogically and mathematically is discussed below.

Much of the text of Volume I is repeated here to provide for a smoother presentation of the material. A notable exception is the background or historical treatment for which the reader is referred to Volume I. In addition this volume contains two Appendices which should prove useful to the non specialist in the area. The first is

a detailed bibliography of papers which are related to the current work and the second is a short tutorial of demand modelling so as to acquaint the non specialist with the terminology and the mathematical formulation normally used.

SECTION I

TESTS OF CURRENT AIR TRAVEL DEMAND MODELS

Several existing models used in forecasting air travel demand have been evaluated to determine the capability of these models for predicting future conditions. Each model was tested with data from a future year relative to the year in which it was calibrated. Actual data for the independent variables were compiled for the year 1974. The models were then used to calculate predicted demand, and this predicted demand was compared with the actual data for 1974. Direct comparisons can be made between predicted and actual demand, giving an indication of the capability of each model. 1974 was selected as the test year since it was the latest year for which all necessary data were available. Three states were selected for the evaluation; Virginia, Oregon and Michigan. These states were selected since models developed specifically for them had significantly different approaches and they represented different geographic regions.

Virginia State Model

1. Form of the Model

The first model to be tested was the model developed for the Virginia Air Transportation System Study. (Va. Div. of Aero. 1975). This model is an economic, aggregate type used to forecast enplanements at an airport based upon system and regional attributes. The model is written as

$$\ln \frac{E'_i}{P_i} = - 10.8444 - .172007F + 1.41311 \ln Y_i \quad (1)$$

P_i = population of airport region i

E'_i = predicted potential for enplanements at airport i .

F = U. S. average airfare/mile (¢/mile, 1967 dollars)

Y_i = per capita income of airport i service area (1967 \$)

Eq. (1) was developed by finding the system and regional attributes which most significantly correlated with trends in air activity, and by using regression analysis to determine the final form of the equation and the coefficients.

Note that this equation predicts a "potential" for enplanements; that is, the demand which would exist if the independent variables are the only ones which affect the number of enplanements. However, other factors not explicitly presented in Eq. (1) have an effect, and they are accounted for by use of a correction factor β_i , as shown below:

$$E_i = \beta_i E'_i \quad (2)$$

where E_i = predicted enplanements at airport i .

β_i = correction factor for airport i .

E'_i = predicted potential for enplanements at airport i .

In the Virginia Air Transportation System Study, β_i for each Virginia airport was determined in the following manner: (1) Eq. (1) was used to predict potential enplanements at each Virginia airport for the year 1970; (2) actual enplanements for each Virginia airport for 1970 were found; and (3) the value of β_i for each airport was determined as the ratio of actual 1970 enplanements to predicted potential for enplanements for 1970. This value of β_i was then considered to remain constant for future years.

2. Data Analysis

Verification of this model was undertaken using data from three states - Virginia, Michigan and Oregon. The results are presented in Tables 1a-c.

Errors (i.e., $100 (E_i / \text{Actual Enplanements}) - 100\%$) vs. Actual Enplanements are plotted for Virginia, Michigan and Oregon in Figures 1a-c. For Virginia, all airports except Roanoke showed errors which were positive; that is, the predicted enplanements were greater than the actual enplanements. For Michigan and Oregon, the opposite situation occurred; 17 of 19 Michigan airports and 8 of 9 Oregon airports had negative errors; that is, predicted enplanements were less than the actual enplanements. Errors were small for large airports (e.g., Norfolk +5%; Detroit, -4%; Portland -1%). However, errors for small airports (under 100,000 in actual enplanements) were wide in range.

3. Sources of Error

A large source of these errors can be attributed to the calculation of the correction factor β_i for each airport. The value of β_i for each airport was determined as the ratio of actual 1970 enplanements to the predicted potential enplanements for 1970. It was assumed that this value of β_i would remain constant for the years beyond 1970.

To have computed β_i based upon only one year, 1970, does not seem to be a satisfactory method. The problem is illustrated in Figure 2a-c. These three figures show the historical trend of enplanements for the years 1962 through 1974 for three airports which

exhibited large errors in enplanements predicted: Roanoke, Va. (-19% error); Lansing, Mich. (-24%); and Pendleton, Ore. (-25%). For each airport, it can be seen that the growth in enplanements levelled off (for Roanoke), or enplanements actually decreased (for Lansing and Pendleton) in 1970, and then enplanements increased during the period 1972-1974. For these airports where a noticeable fluctuation in enplanements occurred, it would have been better to calculate β_i based upon an historical trend in enplanements, and not just upon the one year 1970. The values of β_i for Roanoke, Lansing, and Pendleton were lower than what would have been achieved if the correction factors had been calculated upon an historical trend, and thus the results from Eq. (1) were predicted enplanements which were lower than actual enplanements for 1974.

Aside from the problem of calculating the correction factor β_i , the Virginia Air Transportation System Study Model performed well when real data for the independent variables were used in this verification test. However, the ability to accurately forecast the independent variables is necessary in order for the model to be used as a forecasting tool.

The authors of the Virginia Air Transportation System Study Model made projections concerning future values of the Consumer Price Index and Real U. S. Average Airfare per Mile. The Real U. S. Average Airfare per Mile is one of the independent variables of this model, and the Consumer Price Index is used in computing this Airfare variable, and also the Real Per Capital Income variable (Y_i), in terms of 1967 dollar values.

Table 2a presents the Virginia Air Transportation System Study projections for the Consumer Price Index and Real U. S. Average Airfare per Mile for the years 1973 - 1976. Figures 3a and 3b compare predicted and actual values for Consumer Price Index and Real Average Airfare per Mile, respectively. For 1974, predicted values were below the actual values for Consumer Price Index and Real Average Airfare per Mile. For 1975 - 1976, the discrepancy between actual and predicted values of the Consumer Price Index became greater. While the Real Average Airfare per Mile in 1975 - 1976 was close to the predicted value, this was due to an offsetting error in forecasting Average Airfare per Mile, as shown in Tables 2a and 2b.

Without a good forecasting technique to accurately predict the Consumer Price Index, it is likely that two of the independent variables in Eq. (1), Real Average Airfare per Mile and Real Per Capital Income, will be forecast incorrectly. The inability to forecast independent variables is a major problem in using the Virginia Air Transportation System Study model.

Washington State Plan Model

1. Form of the Model

The second model to be evaluated was the Washington State Airport System Plan Model, (Aerospace Corp., 1973). It is a historical share of the market model, and is given by

$$E_i = M_{i/j} M_j^M / S^M \cdot U.S. E_{U.S.} \quad (3)$$

where E_i = predicted enplanements at airport i.

$M_{i/j}$ = percentage market share for airport i of the total scheduled domestic enplanements of region j in which airport i is located.

$M_{j/S}$ = percentage market share for region j of the total scheduled domestic enplanements of state S.

$M_{S/U.S.}$ = percentage market share for state S of the total scheduled domestic enplanements in the United States.

$E_{U.S.}$ = total scheduled domestic enplanements in the United States.

2. Data Analysis

These market shares were developed for the state of Washington in the following manner: (1) the Washington State percentage of the total U. S. enplanements was calculated for the years 1962-1970. Seattle/Tacoma International Airport enplanements were excluded. Seattle is the dominant airport in the state, and fluctuations in enplanements at Seattle due to military travel and employment changes in the Puget Sound area produced large fluctuations in the data. A historical trend of Washington State's (minus Seattle) percentage of total U. S. enplanements was plotted, and a constant percentage was forecast for fiscal year 1977 and beyond. This historical trend plot is presented in Figure 4a; (2) Washington was divided into three regions, associated with Rand McNally Major Trading Areas. The area around Seattle (although Seattle/Tacoma International Airport was excluded from enplanement data) was designated Region I. The area around Spokane was designated Region II. Region III was considered part of the Portland, Oregon area, and was excluded from further calculations. This was done because Region III scheduled air carrier passengers were assumed to be attracted to Portland International Airport (there is no scheduled aircarrier airport in Region III in

Washington). Historical trends of percentage market share of Region I and Region II were made in a manner similar to Figure 4a, and projected constant market shares were made for the year 1977 and beyond; (3) for each airport in Regions I and II, an historical trend was developed for percentage market share of airport to region, just as was done in the two previous steps.

Verification of the Washington State System Airport Plan Model was conducted by testing the model in three states: Washington, Virginia and Oregon, using actual 1974 enplanement figures for total U. S. enplanements. The results for Washington are presented in Table 3a. The major problem with verification of the model in Washington State was the significant decline of certificated air carrier service to a number of Washington airports, and their replacement with scheduled air commuter flights, for which enplanement data for 1974 could not be found. Approximate enplanement figures were calculated using data from an Official Airline Guide, North American Edition, July 1, 1974. The relationship for annual commuter enplanements, E, was assumed to be approximated by

$$E = 52 \sum_x N_{x_i} C_x L_x \quad (4)$$

where N_{x_i} = number of flights per week of aircraft type x departing airport i.

C_x = passenger capacity of aircraft x.

L_x = average load factor of aircraft x.

Results of using Eq. (4) are shown in Table 3a. An average load factor of 0.40 was used in all calculations. Another irregularity

occurred in the results for Washington State, although it was apparent for only one city, Spokane. Spokane was the host city to a World's Fair in 1974, and passenger enplanements were about 85,000 higher than predicted. This special event was probably the major reason for this difference. The effect the World's Fair had on the enplanements of other airports is not possible to gauge because of the lack of certainty concerning commuter enplanements.

Although the Washington State Airport System Study Plan Model was designed as a forecasting method for the state of Washington, the problems discussed above have made it impossible to correctly judge its capability.

To test the Washington State System Airport Plan Model when applied to Virginia and Oregon it was necessary to develop the historical trend curves of the market shares. This was done in a manner similar to the method used by the authors of the Washington State System Airport Plan; the only significant difference was the omission of dividing the state into regions. Instead, percentage market shares of the airports were calculated with respect to the total enplanements in the state. Eq. (3) was modified to the following form:

$$E_i = M_{i/S} M_{S/U.S.} E_{U.S.} \quad (5)$$

where $M_{i/S}$ = percentage market share for airport i of the total scheduled enplanements of state S.

$$E_{i, M_{S/U.S.}, E_{U.S.}} = \text{same as in Eq. (3).}$$

The historical trend curves for Virginia airports are presented in Fig. 4b. Danville and Hot Springs do not appear because their percentage market shares of the Virginia total were under 1%.

Tables 3b and 3c are the results of the modified Washington State System Airport Plan Model for Virginia and Oregon, respectively, using actual enplanement data for 1974 for the variable $E_{U.S.}$.

3. Sources of Error

Figure 5a shows the error vs. actual enplanements for Virginia airports. The model seems to be a good forecasting tool only for larger airports; that is, airports with enplanements greater than 300,000. Enplanements at small airports were difficult to forecast because a small error in the forecast percentage market share, M_i/S , would cause a significant change in the predicted enplanements. For larger airports, however, a difference of 1% or 2% in the prediction of variable M_i/S would not greatly affect predicted enplanements. This is shown to be true for Oregon airports also, as seen in Figure 5b. The larger airports, Eugene and Medford (which have a combined market share of 76% of the state total) were predicted very accurately, while the results for the smaller airports showed a large range in errors. Notice that Portland was excluded from the calculations in Oregon. Portland is the dominant airport in the state (82.4% of all Oregon enplanements occurred at Portland in 1974), and to have included it in the market share analysis would have made the market shares so small for the other Oregon airports, it would have been impossible to achieve any dependable market share forecasts.

In summary, the market share model has been shown to be a good forecasting tool only for airports which have a large market share of the state total. It is very difficult to make accurate forecasts for small airports. A further drawback is the need to obtain historical data in order to develop the market share percentage, which makes this technique unusable for predicting enplanements at a new airport where no historical data exist.

Michigan State Plan

1. Form of the Model

The Michigan State Airport System Plan Model (Stanford Research Institute, 1974) was the last of the state plan models to be tested. Total travel between two regions and travel by each mode between two regions were the quantities which this model was designed to calculate. An outline of the methodology will be presented here. First, a travel "conductance" for each mode was defined as follows:

$$w_m = a_m t_m^{\alpha_m(1)} c_m^{\alpha_m(2)} \{1 - \exp(-.12 f_m)\}^{\alpha_m(3)} \quad (6)$$

where w_m = travel conductance for mode m between region i and region j .

t_m = travel time between region i and region j by mode m .

c_m = cost of travel between region i and region j by mode m .

f_m = frequency of service between region i and region j by mode m .

$a_m, \alpha_m(1), \alpha_m(2), \alpha_m(3)$ = mode-specific calibration parameters.

A total travel "conductance" is defined as:

$$W = \sum_m w_m \quad (7)$$

where W = total travel conductance between region i and region j .

w_m = travel conductance for mode m between region i and region j.

Next, the total predicted passenger travel between two regions, i and j, can be expressed by the following equation:

$$T_{ij} = \beta_i \beta_j P_i P_j W^{0.9} \quad (8)$$

where T_{ij} = predicted total travel between region i and region j.

$\beta_i \beta_j$ = regional constants for region i and region j, respectively.

P_i, P_j = populations of region i and region j, respectively.

W = total travel conductance between region i and region j.

Travel between two regions for a single mode is thus defined as

$$T_{mij} = \frac{w_m}{W} T_{ij} \quad (9)$$

where T_{mij} = predicted travel by mode m between region i and region j.

w_m = travel conductance for mode m between region i and region j.

W = total travel conductance between region i and region j.

Substituting the expression for T_{ij} of Equation (8) in Eq. (9)

yields the following equation for travel by mode m between two regions:

$$T_{mij} = \frac{w_m}{W} \beta_i \beta_j P_i P_j W^{0.9} \quad (10)$$

As air is the mode of interest, a working equation for calculations can be achieved by substituting the expressions for w_m and W into Eq. (10):

$$T_{air,ij} = \frac{\alpha_{air}^{(1)} \alpha_{air}^{(2)} \alpha_{air}^{(3)} a_{air} t_{air} c_{air} \{1 - \exp(-.12 f_{air})\}}{\left\{ \sum_m \frac{\alpha_m^{(1)} \alpha_m^{(2)} \alpha_m^{(3)} a_m t_m c_m \{1 - \exp(-.12 f_m)\}}{\alpha_m^{(3)}} \right\}^{.1}} \beta_i \beta_j P_i P_j \quad (11)$$

The values for the mode specific calibration parameters, as presented in the Michigan State Airport System Plan, are shown in Table 4a.

As the air mode was the only mode of interest, it was desirable to find some way of approximating the denominator of Eq. (11) in order to avoid the long and tedious process of calculating conductance values for all modes. The following was the method used to approximate $W^{0.1}$: (1) three cities, Roanoke, Dallas and San Francisco were chosen, and the travel conductance for trips between Charlottesville, Virginia and these three cities were calculated. Charlottesville was chosen because of familiarity with the transportation systems in the area, and the three destination cities, although somewhat arbitrarily chosen, were selected because each was a particular distance away from Charlottesville: Roanoke is short haul (88 air miles); Dallas is medium-long haul (1,100 air miles); and San Francisco is long-haul (2,400 miles); (2) the values of w_m , Q , and $W^{0.1}$ were calculated for the three city pairs, and the results are presented in Table 4b; (3) using these three points, a smooth curve was drawn, showing $W^{0.1}$ as a function of air distance. This curve is shown in Figure 6a, and was used as a calibration curve to obtain approximate values of $W^{0.1}$.

2. Data Analysis

The state of Michigan was divided into 27 regions (see Figure 6b). Some regions did not have their own airports, and were dependent upon a neighboring region for air service. The continental United States

outside of Michigan was divided into 20 regions as shown in Figure 6c. The external regions surrounding Michigan were small in land area, constituting only parts of neighboring states. As distance away from Michigan increased, regions increased in size, constituting groups of states.

Each region, both within and outside Michigan was given a region constant and a "gateway" city was selected as the representative city of the entire region for the purpose of calculation. A list of each region, its gateway city, and value of its regional constant is presented in Table 4c.

Sample calculations for air travel between regions were performed, using Region 8, Grand Rapids, Michigan, as the region of origin. The results of these calculations are presented in Table 4d. It was not possible to obtain data for 1974 which could be compared directly with these calculated results. The best available data was from the Origin-Destination Survey of Airline Passenger Traffic, Table 8, compiled by the Civil Aeronautics Board, for the 12-month period from April 1, 1972, to March 31, 1973. The data is presented as the number of passengers between city pairs, based upon 10% of all tickets issued nationwide. Therefore, the approximate number of passengers who traveled between two cities (traffic in both directions) can be obtained by multiplying by 10, and approximate one-way travel can be obtained by dividing by 2. These results are shown in Table 4d. It is difficult to directly compare these results, as the figures obtained from the CAB table are not for 1974, but from

over a year earlier. Also, the calculations performed by use of the Michigan State Airport System Plan were not city pair calculations, but calculations for travel between regions, where some regions encompass several states. The state of Michigan is divided into enough regions so that almost every region has at most one airport. Therefore, Region 8 is roughly equivalent to the actual region which is served by Grand Rapids Airport. However, a Region like Region 44, which consists of Colorado, Utah, New Mexico, Arizona, and Nevada, contains many large cities with their own airports. The gateway city of Denver is a representative city of the region used in the calculations, but the calculated result should indicate air travel from Grand Rapids to all cities in that region. This makes direct comparisons difficult, although it is obvious that the calculated results for travel to regions outside of Michigan should be larger than the figures from the CAB table. For travel within Michigan, the opposite problem sometimes occurred when a region had no airport. These regions had their populations added to the population of the closest region with an airport.

3. Sources of Error

Possible errors have occurred from the following factors: (1) the use of Figure 6a was only as an approximate calibration curve, and did not take into account the unique problem encountered in traveling by ground from Grand Rapids to certain regions outside Michigan due to the necessity of having to skirt the Great Lakes; (2) severe weather in the winter in the Great Lakes region would probably cause

a shift in auto travel to air travel between certain regions. It is not known if the regional constants were calibrated to take into account such a problem.

For the reasons explained above, the results of testing the Michigan State Airport System Model are inconclusive. However, the errors indicate that the predictions are much too low in general.

Study of travel demand between pairs of regions provides more insight into the travel patterns of a community than to merely predict total departures without regard to destination.

The testing of these three models shows different techniques for forecasting air travel demand and highlights various shortcomings in each. A common situation which has been encountered with each of these techniques has been the omission or inability to explicitly include all important factors which affect the travelmaking decision.

SECTION II

VARIABLES OF INTEREST

In order to better model the demand for air travel between cities an investigation of the variables most likely to account for the differences in travel patterns was undertaken. There have been many studies in the literature, both in intra-and inter-city demand analyses which have tried varieties of variables. Most of the work has centered on the use of econometric type models, however a few have attempted to use non-conventional variables. Table 5 summarizes some of the work in the inter-city arena. In some cases (e.g. the work by Yu, 1970) the significance of each of the variables tried is discussed. In most cases it is not. In addition to the variable type the question should be asked, what is the proper form for the variable? That is, is it more appropriate for the variables to appear in a product form or in a summation - or perhaps some other representation. A complete investigation of this is beyond the scope of this work, however several authors have shown that the product approach yields better agreement with actual data.

In an attempt to analyze some of the variables several correlational studies were made. In these trips were subdivided in several ways - 200 mile increments, 100,000 population increments, etc. Variables considered included, white collar workers, wholesale trade, home owners, manufacturing workers, college graduates, value added, no. of households with more than \$15,000 in income, total income, retail sales, distance, and population. Plots of several of these are shown in figure 7a through 7d. The first three of these show a

significant correlation for no. of white collar workers, per capita income and no. of manufacturing workers. The fourth (7d) indicates the lack of any relationship with college education. Table 6 summarizes the results of this study.

TABLE 6

SIGNIFICANCE OF MODEL VARIABLES

Variable	Significance
White collar workers	S
Wholesale trade	S
Homeowners	S
Manufacturing workers	S
College graduates	I
Value Added	I
Salaries over \$15,000	I
Income	I
Retail sales	I
Population	S
Distance	S

In addition to the above both additive forms of each of the variables and product forms were tested. In all cases where the variable was judged significant the product form was superior.

SECTION III

DEVELOPMENT OF A NEW AIR DEMAND MODEL

The results of the tests performed on present air demand models shows the need for more sophisticated modeling techniques in order to achieve an accurate forecasting tool. From a study of the literature, it is apparent that the travel habits of different groups of people differ. Considerable research has been done in an attempt to find the most important factors which influence air travel (e.g., Kuhlthau and Jacobson, 1976, Jacobson and Kuhlthau, 1972, Lee and Jacobson, 1972, Port of N. Y. Authority, 1957, Federal Aviation Agency, 1963, and Federal Aviation Administration, 1976). From these and the findings of the previous section a list of the factors considered to be most important are presented in Table 7. Also, it has been shown that the traveling public can be divided into distinct groups according to the purpose of the trip, (Yu, 1970, Lee and Jacobson, 1972, Port of N. Y. Authority, 1957). Different factors influence the travel decision process according to the purpose of the trip; therefore, a new air demand model should segment air demand due to business travel and air demand due to pleasure travel. Several other market segmentations may also be necessary.

From a purely mathematical viewpoint using nonsegmented data can lead to incorrect assumption when doing regression analyses. This has been discussed by Hensher (Hensher, 1976) who pointed out the difficulties which can be encountered. For example, consider the variation in number of trips generated between city i and city

j with income. Consider two groups - those with high education and those with low education levels. The data might well be distributed as shown in Figure 8. The actual behavior with income variation as predicted by linear regression would not accurately represent the true travel behavior. If the market were segmented by education level then true behavior would be represented.

It is felt that most of the major shortcomings of past aggregate models has been their inability to segment the data properly. The natural end point for this segmentation is behavior on an individual level - what is commonly referred to as disaggregate modeling. For intercity travel - as opposed to intracity travel - the ability to use market segmentation to disaggregate the data offers a useful alternative to the extreme of individual behavior. It has some of the same advantages of the treatment of individual data - e.g., requires less information for modeling since only a limited number of data points is needed in each cell (segmentation). And, it does not suffer from the drawbacks of complete aggregation - e.g., nonlinear effects lost in data pooling.

Two of the three models investigated - the Virginia and Washington State Plan Models - were designed only to forecast total enplanements from a region. These models lacked the capability to determine the demand from the region under study to particular destination regions. The Michigan State Plan Model did provide the methodology necessary to study demand between particular regions, thus providing a greater understanding into the nature of the demand.

A new air demand model should investigate the demand between pairs of regions, and the total demand for air travel in a particular region can be simply calculated by summing the demands from that region to all destination regions.

Form of Proposed Models

The following equations are proposed which will segment the demand. At the minimum, segmentation should be by purpose of trip.

Here air demand for business is proposed to be the following:

$$T_{ijb} = f_{lb}(t,d) \frac{P_i^{\alpha_2} P_j^{\alpha_2}}{\alpha_3} Ch_i^{\alpha_4} Ch_j^{\alpha_5} \{g_{1b}^{\alpha_6} T_{ij}^{\alpha_7} E_{ijb}^{\alpha_8} + g_{2b}^{\alpha_9} W_{ij}^{\alpha_{10}} C_{ij}^{\alpha_{10}}\} R_{ij}^{\alpha_{10}} D_{ij}^{\alpha_{10}} \quad (12)$$

where T_{ijb} = number of air travelers from region i to region j for business purposes.

$f_{lb}(t,d)$ = function of length of stay in region j and distance between regions i and j.

P_i, P_j = populations of regions i and j, respectively.

D_{ij} = distance from region i to region j.

Ch_i, Ch_j = industrial characteristics of regions i and j, respectively.

g_{1b} = function of air mode system characteristics

T_{ij} = travel time from region i to region j by air mode

E_{ijb} = convenience of air mode from region i to region j (e.g., scheduling, number of seats available during peak travel hours, ease of airport access and access)

g_{2b} = function of air mode comfort characteristics (e.g., seat comfort, ride quality, etc.)

W_{ij} = ability to work while traveling (e.g., space to work,
ability to read and write, ect.)

C_{ij} = comfort characteristics (e.g., seat comfort, ride quality,
etc.)

R_{ij} = road conditions between i and j

Notice Eq. (12) contains a term which is the produce of the two regional populations divided by the distance between them; such a term is called a "gravity" term because of its similarity to the equation describing the gravitational attraction of two physical objects. The gravity term is considered the basis of attraction between the two regions i and j, and therefore the basis of travel between them. It is modified by the industrial characteristics of the regions to account for the fact that certain industries have greater travel needs than others (Port of N.Y. Authority, 1957, Federal Aviation Agency, 1963). Regions can be classified according to the type of businesses which are the most important. For example, an FAA study of the business characteristics of metropolitan areas, classified each area in one of four categories: (1) marketing center; (2) institutional (e.g., government or academic); (3) industrial (e.g., manufacturing); (4) balanced, i.e., none of the three types were dominant. The general findings of this study were that marketing centers and institutional center were heavy users of air travel, while industrial centers were slow users by comparison, and balanced cities were average users (Figure 9). Thus, given two regions of the same population size, a marketing center would enplane more

passengers than a manufacturing (industrial) center. The industrial characteristics variables in Eq. (12) act as modifiers of the population variables.

The function $f_{1b}(t,d)$ is another modifier of the gravity term. This function represents the personal decision making process to use air rather than another mode, based upon the distance of the trip and the length of stay at the destination. For example, a 300-mile trip for a day clearly necessitates the use of air, whereas a trip of 300 miles for a week's duration may be more practical by auto (especially if an auto would be needed at the destination during the weeklong stay). Generically this function might appear as shown in Figure 10.

The remaining terms in Eq. (12) can be considered system attributes which modify the basic personal and regional demands for air travel. Total travel time by air and convenience of the air mode represent the two most important system attributes, and could be considered "air advantage" variables; that is, would reflect the superiority (or inferiority) of the air mode versus other available modes for the business trip. The last two variables, ability to work and comfort, represent "personal taste" of the traveler, and again reflect a potential advantage or disadvantage for the air mode compared with other modes.

Notice that some of the factors listed in Table 5 are not included in Eq. (12). In business travel decisions these factors are not considered important in the process of travel choice. Of the

mode variables, comfort and convenience were used in the model, but cost, reliability, and safety were not. Cost has been found to be a relatively non-critical factor for business travelers. (Lee, W. and Jacobson, I. D., 1972). Reliability and safety are important, but the business traveler considers both of these to be very good for the air mode, and therefore not critical in the decision making process. Service is related to comfort and convenience, which are included in the model, and speed is related to travel time.

No personal variables were included. For business travelers, these four factors are highly interrelated, and are also related to the industrial characteristics of the region. Likewise employment can be considered as part of the regional industrial characteristics.

Of the trip variables, purpose of trip has been considered to be the most important, and has been used as the means of disaggregating the traveling public. All other trip variables are included in Eq. (12), except for the size of the traveling party, which was considered unimportant.

In the same manner that an equation for air demand for business purposes was developed, an equation for pleasure travel demand was formulated, and is shown below:

$$T_{ijp} = f_{lp}(t, d, p, S) \frac{\beta_1 \beta_2}{\beta_3} \frac{I_i A_j R_{ij}}{D_{ij}} \{ g_{ip} S_{ij} T_{ij} E_{ijp} + g_{2p} R_{ij} S_{ij} \} \quad (13)$$

where T_{ijp} = number of air travelers from region i to region j, for pleasure purposes.

$f_{lp}(t,d,p,s)$ = function of length of stay in region j, distance between regions i and j, number of people in the party, and number of stops (other secondary destinations), in itinerary.

P_i, P_j = populations of region i and j, respectively.

D_{ij} = distance from region i and region j.

I_i = income distribution in region i.

A_j = attractiveness of region j.

R_{ij} = road conditions between i and j.

g_{lp} = function of air mode system characteristics.

$\$_{ij}$ = cost of air travel from region i to region j.

T_{ij} = travel time from region i to region j by air mode.

E_{ijp} = convenience of air mode from region i to region j
(different from convenience as perceived by business traveler)

g_{2p} = function of air mode dependability characteristics as perceived by pleasure travelers.

R_{ij} = reliability of air mode (e.g., on-time performance)

S_{ij} = safety of air mode as perceived by pleasure travelers.

Eq. (13) is similar in form to Eq. (12). Once again, the gravity term is the basis for the attraction between the two regions. Instead of industrial characteristics of the two regions, the income distribution of region i and the attractiveness of region j are the modifiers used. Regions of high attractive value would be places which attract a large number of tourists (e.g., Florida, California, etc.).

As with business travelers, the length of stay and distance would play a role in the decision making process, and also the number of people traveling together (i.e., individual, adult couple, entire family, etc.), and the number of places planned to be visited enroute (e.g., a vacation trip in which it is desired to visit all attractive regions in Florida or California, etc.), would come into consideration. See Figures 11 and 12.

As for the mode variables, travel time and convenience are included, although "convenience" for a pleasure traveler is probably different than for a businessman. For example, a pleasure traveler would be interested in a flight which would have discount seats, whereas a businessman would be concerned with finding a flight which best matches his business itinerary. Cost is a very important factor in pleasure travel, and safety and reliability also play an important part in decision making. Fear of flying is still a strong negative factor among a sizeable fraction of the traveling public, and is probably strongest among people who have never used air travel before. Although this is probably due to a lack of familiarity with air travel, it is still a problem that needs to be overcome before air travel becomes a serious consideration in planning a pleasure trip.

Combined Model

Although the above models represent a conceptual approach to the problem it is important to note that not all of the variables can be easily obtained. A good example of this is illustrated by the dependent variables for the number of business and pleasure

travelers, T_{ijb} and T_{ijp} . It is a good approximation that the national total of air travel is divided between business and pleasure travelers at 70% for business and 30% for pleasure. However, there is no certainty that a given pair of regions will have a business/pleasure composition of traffic that is near the 70%/30% figure.

Likewise, the function $f_1(t,d)$ in Eq. (12) and the function $f_1(t,d,p,s)$ in Eq. (13), while qualitatively obvious, are not easy to quantify.

Because of these problems a combined equation was created and tested. Not to prove the correctness of the model chosen -- but to test the need for some of the less conventional variables.

To this end a subset of the above variables was chosen for analysis. These included:

- o population of city i, P_i
- o population of city j, P_j
- o distance between city i and j, D_{ij}
- o road conditions around city i to airport in city i, R_i
- o road conditions around city j to airport in city j, R_j
- o attractiveness of city i, A_i
- o attractiveness of city j, A_j
- o number of seats available, S_{ij}
- o characteristics of city i, Ch_i
- o characteristics of city j, Ch_j
- o reliability of flights, K_{ij}
- o cost, $\$_{ij}$
- o time, T_{ij}

Selection of Cities

Table 8 provides the list of all cities which are considered in this study. City pairs were selected considering the following:

- o range (short/medium/long)
- o population (low/medium/high)

In the beginning, 35 pair of cities were selected which were subsequently increased to 251. This was done to test the model(s) at various levels of disaggregation. Pairs of cities are listed in Table 9 with data for 1974. Data for 1970 is given in Table 10.

The community with an airport can be described in terms of the air traffic handled at its airport, and vice versa; an airport reflects the characteristics of the community it serves. The amount of air traffic volume generated by a community is related to the size of the community; that is, large metropolitan areas generate more air traffic than small cities. Traffic variations within a population-size group, however, reflect community differences in economic character and other factors of the region.

Variables

Travel cost is the expense in going from the central city of region i to the central city of the region j. The travel cost is calculated by adding the following three costs:

- o coach air fare from the airport of region i to the airport of region j.
- o the cost to reach the airport from the central city in region i.
- o the cost to reach the central city from the airport in region j.

Travel time is defined as the time spent in going from the central city of region i to the central city of the region j. It is the summation of the following four elements.

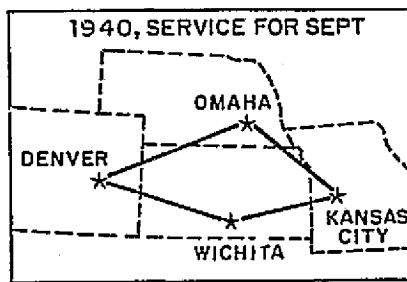
- o travel time from central city to airport in region i.
- o travel time from airport to the central city in region j.
- o actual flight time from the airport in region i to the airport in region j.
- o 45 minutes for ticket and luggage check in at region i and luggage check out at region j.

Reliability was measured as the percentage of the scheduled flights from the airport at region i which actually departed in the year under consideration.

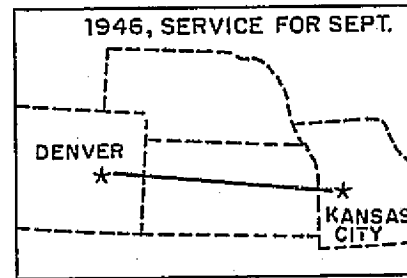
Direct airline connections and routes are a prerequisite to the development of the airline passenger potential. Figure 13 compares the air traffic relationship between Kansas City and Denver in 1940 when the routes included Omaha and Wichita as intermediate stops and, in 1946, after direct service had been instituted. The increase in the number of passengers traveling between the pair of cities is apparent from the following (FAA, 1963).

	<u>1940</u>	<u>1946</u>
Passengers between Denver and Kansas City	29	1,484
Percent of Denver's total traffic	1.20	5.70
Percent of Kansas City's total traffic	0.21	4.63

PASSENGERS BETWEEN DENVER AND KANSAS CITY



Change of airline necessary at
either Wichita or Omaha



Direct Route

Figure 13. Direct Route Passenger Service Generates More Traffic Than Indirect Connections

Thus, the number of passengers between two cities is directly proportional to the number of direct flights without stoppage and, to a lesser extent, to the number of direct flights with stops and the connecting flights.

Generally, the purpose of trip is either pleasure or business. Short distance trips can be considered as business trips. When purpose of the trip is included in the model, the level of service/comfort can be taken as the number of seats available during the morning hours, i.e., on flights arriving at airport in region j by noon, for short distance flights. This will take into account the businessmen's needs for morning departure for one day trip. This criterion was not used for long distance flights because a long-distance trip is hardly ever a one day trip, so that morning departure, even for a business trip, is not as critical as for short flights. For long-distance flights, level of service represents the number of seats available in one day. The procedure to calculate the number of seats is described in the next section of the report.

When the purpose of the trip is not considered in the model, level of service is considered as a function of the number of available seats and is same for both long distance and short distance flights.

Attractiveness of the cities also affects the number of enplanements; that is, famous cities with many tourist and/or business attractions generate more air traffic than cities with little attraction.

The communities are classified according to whether the community earned its livelihood primarily by trade and/or industry. Accordingly, communities were divided into four categories: Industrial Communities, Marketing Centers, Institutional Communities, and Balanced Communities.

Marketing Centers have wholesale sales per capita that are significantly above average and a percentage of industrial employment that is below average; criteria for Industrial Communities are the reverse. Balanced Communities have "around average" counts for both criteria; while Institutional Communities are "negative" because their primary economic livelihood is derived, at least in part from activities not directly related to either trade or industry. Table 11 classifies the cities in these four categories.

Considering these independent variables, the proposed model for the calculation of the number of enplanements between two cities i and j is

$$T_{ij} = x_o P_i^{\alpha_1} P_j^{\alpha_2} D_{ij}^{\alpha_3} S_{ij}^{\alpha_4} TT_{ij}^{\alpha_5} F_{ij}^{\alpha_6} ST_{ij}^{\alpha_7} A_i^{\alpha_8} R_i^{\alpha_9} K_i^{\alpha_{10}} Ch_i^{\alpha_{11}} Ch_j^{\alpha_{12}} \quad (14)$$

where T_{ij} = no. of enplanements from region i to region j

P_i, P_j = population of regions i and j , respectively (in 1000's)

D_{ij} = distance from region i to region j
 S_{ij} = cost of air travel from region i to region j
 TT_{ij} = travel time from region i to region j
 F_{ij} = no. of flights from region i to region j
 ST_{ij} = no. of available seats in planes from region i to region j
 A_i = attractiveness of city i
 A_j = attractiveness of city j
 R_i = road conditions of city i
 R_j = road conditions of city j
 K_i = reliability of service at region i
 Ch_i = characteristic of city i
 Ch_j = characteristic of city j

Relative attractiveness of the cities were compared and values were given to each city out of a maximum of 20 (where 0 is very little attraction and 20 highly attractive). Road conditions were also compared and values assigned to each city out of a maximum of 10 (where 0 is very poor and 10 excellent). The definitions of each of these variables is summarized in Table 12.

Many regression models were run using data from the 251 city pairs. Various combinations of parameters were tried and various forms of the model evaluated. Based on these a model for trips from city i to city j, T_{ij} where the distance is greater than 300 miles is given by

$$T_{ij} = 1.34 \times 10^{-5} \frac{P_i^{.62} P_j^{.35}}{D_{ij}^{.58}} R_i^{4.88} A_j^{.03} S_{ij}^{1.25} F_{ij}^{.38} Ch_i^{-.38} Ch_j^{-1.04} \quad (15)$$

where the number of flights F_{ij} is given by

$$\begin{aligned} & \text{No. of direct flights} + \frac{\text{No. of direct flights (1 stop)}}{2} + \frac{\text{no. of direct flights (2 or more stops)}}{3} \\ & + \frac{\text{No. of connecting flights (no stop in either segment of trip)}}{4} + \frac{\text{No. of connecting flights (one stop)}}{6} \\ & + \frac{\text{No. of connecting flights (2 or more stops)}}{8}; \end{aligned}$$

and the number of seats S_{ij} by

$$\begin{aligned} & \frac{\text{No. of seats in direct flight (DF) (no stops)}}{1} + \frac{\text{No. of seats in DF (one stop)}}{2} \\ & + \frac{\text{No. of seats in DF (2 or more stops)}}{4} + \frac{\text{No. of seats in connecting flights (CF) (no stop in either segment of trip)}}{10} \\ & + \frac{\text{No. of seats in CF (1 stop)}}{8} + \frac{\text{No. of seats in CF (2 or more stops)}}{10} \end{aligned}$$

The characteristics of city i and j are the percent employed in manufacturing and wholesale and retail trade respectively.

Details of this model are given in Table 13.

TABLE 13

Variable	Exponent	Std. Error	F	Significance
P_i	.62	.10	39.7	.00
P_j	.35	.08	21.6	.00
D_{ij}	-.58	.12	22.1	.00
R_i	4.88	2.43	4.1	.05
A_j	.03	.11	.09	.76
S_{ij}	.33	.15	4.8	.03
F_{ij}	.39	.18	4.5	.04
Ch_i	-.28	.13	4.5	.04
Ch_j	-.85	.52	2.6	.11

Several points are worth noting here. First, conspicuous by its absence is the time variable. This is due to the fact that time and distance are highly interrelated for a single mode and thus the effect of time is embedded in the distance variable. Another point to note is the negative exponents on the city characteristics. This implies that the more manufacturing (and thus less government, education, professional, etc.) the fewer trips generated in region i and the more retail trade (less government, education, profession and manufacturing) the fewer trips attracted by j. In addition the population of the originating city is more of a determining factor than the population of the destination city.

This model which is significant at better than the .01 level accounts for 93% of the variance in the data; or, has a correlation coefficient of $r=0.963$. It is felt that although this model is a composite model with many assumptions it has demonstrated the ability of non-conventional, more easily forecastable variables to predict demand.

SECTION IV

CONCLUSIONS

Several conclusions can be drawn from this study:

- o a more sophisticated model to predict travel demand is needed
- o many existing variables used to predict demand cannot be forecasted reliably
- o market segmentation is necessary to develop better demand forecasting models
- o non-conventional (i.e. other than cost and time) variables can be used to predict demand
- o there is a distinct lack of data to use for non-economic demand models

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TABLE 1a: Verification Test of Virginia Air Transportation System Study Model for Virginia Airports, 1974

										(1)		
i	Airport	Code	1974 P _i	1974 F	1974 Y _i	1974 E _i	B _i	1974 E _i	Actual Enplane- ments 1974	$\frac{E_i}{\text{Actual}}$	$\frac{E_i}{\text{Act}}$	- 1.00
1	Charlottesville	CHO	137,100	5.508	3056	87,300	.627	54,700	52,900	1.03		+ 3%
2	Danville	DAN	217,800	5.508	2990	134,400	.063	8,500	7,000	1.21		+21%
3	Hot Springs	HSP	5,100	5.508	3770	4,400	1.417	6,200	4,800	1.29		+29%
4	Lynchburg	LYH	175,600	5.508	3203	119,400	.507	60,500	56,000	1.08		+ 8%
5	Newport News	PHF	373,500	5.508	3407	277,200	.800	221,800	200,500	1.11		+11%
6	Norfolk	ORF	817,000	5.508	3361	594,800	1.244	739,900	701,700	1.05		+ 5%
7	Richmond	RIC	942,700	5.508	3723	793,000	.582	461,500	426,500	1.08		+ 8%
8	Roanoke	ROA	490,200	5.508	3033	308,700	.916	282,800	351,200	.81		-19%
9	Staunton (Shen.Valley)	SHD	178,700	5.508	2985	110,000	.204	22,400	21,900	1.02		+ 2%
E								1,878,200	1,772,100	1.06		+ 6%

FOOTNOTES:

- (1) Enplanements are Scheduled Domestic Enplanements for Certificated Air Carriers.
Source: Airport Activity Statistics, 12 Months Ended 31 Dec. 1974

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TABLE 1b: Verification Test of Virginia Air Transportation System: Study Model for Michigan Airports, 1974

(1)												
1	Airport	Code	1974 P _i	1974 F	1974 Y _i	1974 E _i	E _i	1974 E _i	Actual Enplane- ments 1974	$\frac{E_i}{\text{Actual}}$	$\frac{E_i}{\text{Act.}}$	-1.00
1	Alpena	APN	107,800	5.508	2354	47,400	.185	8,800	9,200	.96	- 4%	
2	Benton Harbor	BEH	275,200	5.508	2808	155,400	.172	26,700	30,000	.89	-11%	
3	Detroit	DTT	4,763,600	5.508	3529	3,715,700	.976	3,626,500	3,776,200	.96	- 4%	
4	Escanaba	ESC	46,700	5.508	2488	22,200	.689	15,300	15,400	.99	- 1%	
5	Flint	FNT	580,600	5.508	3022	363,700	.224	81,500	99,600	.82	-18%	
6	Grand Rapids	GRR	722,500	5.508	2966	440,800	.581	256,100	284,600	.90	-10%	
7	Hancock	CMX	46,500	5.508	2158	18,100	.866	15,700	18,800	.84	-16%	
8	Iron Mountain	INT	38,400	5.508	2553	19,000	.837	15,900	16,400	.97	- 3%	
9	Ironwood	IWD	31,700	5.508	2261	13,200	.688	9,100	8,700	1.05	+ 5%	
10	Jackson	JXN	272,100	5.508	2904	161,100	.041	6,600	8,700	.76	-24%	
11	Kalamazoo	AZO	473,400	5.508	3074	303,800	.327	99,300	101,300	.98	- 2%	
12	Lansing	LAN	396,500	5.508	3145	262,800	.466	122,500	160,600	.76	-24%	
13	Manistee	MEL										
14	Menominee	MMN	25,000	5.508	2327	10,800	.859	9,300	9,200	1.01	+ 1%	
15	Marquette	MYT	79,100	5.508	2517	38,300	.742	28,400	29,900	.95	- 5%	
16	Muskegan	MEG	288,900	5.508	2578	144,600	.470	68,000	73,100	.93	- 7%	
17	Pellston	PLN	38,900	5.508	2531	19,000	1.294	24,600	27,100	.91	- 9%	
18	Saginaw	MBS	735,700	5.508	2797	413,200	.394	162,800	170,400	.96	- 4%	
19	Sault Ste. Marie	SSM	53,500	5.508	2224	21,700	.522	11,300	12,300	.92	- 8%	
20	Traverse City	TVC	140,400	5.508	2482	66,600	.850	56,600	64,300	.88	-12%	
E								4,645,000	4,915,800	.94	- 6%	

FOOTNOTES:

(1) Enplanements are Scheduled Domestic Enplanements for Certificated Air Carriers

Source: Airport Activity Statistics, 12 Months Ended 31 Dec. 1974

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TABLE 1c: Verification Test of Virginia Air Transportation System: Study Model for Oregon Airports, 1974

i	Airport	Code	1974	1974	1974	1974	B_i	1974	Actual Enplane-	$\frac{E_i}{\text{Actual}}$	$\frac{E_i}{\text{Act}} - 1.00$
			P1	F	V1	E1		E1	ments 1974	(1)	
1	Astoria	AST	29,100	5.508	3114	19,000	.069	1,300	700	1.86	+86%
2	Eugene	EUG	395,700	5.508	2921	236,300	.483	114,100	136,100	.84	-16%
3	Klamath Falls	LMT	58,900	5.508	2925	35,200	.608	21,400	24,500	.87	-13%
4	Medford	MFR	154,800	5.508	2730	84,000	1.073	90,100	93,900	.96	- 4%
5	North Bend	OTH	73,100	5.508	2942	44,100	.312	13,800	15,500	.89	-11%
6	Pendleton	PDT	80,700	5.508	2905	47,800	.443	21,200	28,200	.75	-25%
7	Portland	PDX	1,181,900	5.508	3436	887,800	1.666	1,479,100	1,501,000	.99	- 1%
8	Redmond	RDM	61,200	5.508	2817	34,700	.145	5,000	7,600	.66	-34%
9	Salem	SLE	290,700	5.508	2921	173,600	.057	9,900	13,200	.75	-25%
Σ								1,755,900	1,820,700	.96	- 4%

FOOTNOTES:

- (1) Enplanements are Scheduled Domestic Enplanements for Certificated Air Carriers
Source: Airport Activity Statistics, 12 Months Ended 31 Dec. 1974

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TABLE 2b: Changes in Consumer Price Index and Real U.S. Average Airfare, 1973-1976

	Increase in C.P.I. over Previous year	C.P.I. (1967=1)	Incr. in U.S. Av. Airfare (¢/mi) over Previous Year	U.S. Av. Air- fare (¢/mi)	Incr. in Real Av. Airfare (Airfare/CPI) (¢/mi) Over Previous Year	Real U.S. Av. Airfare (¢/mi)
1972	--	1.253	--	6.918	--	5.521
1973	+ 6.2%	1.331	+ 1.6%	7.030	-4.3%	5.281
1974	+11.0%	1.477	+15.7%	8.136	+4.3%	5.508
1975	+ 9.1%	1.612	+ 2.2%	8.314	-6.4%	5.158
1976	+ 5.8%	1.705	+ 2.0%	8.480	-3.6%	4.974

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TABLE 3a: Verification Test of Washington State System Airport Plan Model for Washington Airports, 1974

1	Airport	Code	$M_{1/j}$	$N_{j/Wash}$	$M_{Wash/U.S.}$	$E_{U.S.}$	E_i	Actual En- planements 1974 (1)	$\frac{E_i}{Act}$	$\frac{E_i}{Act} - 1.00$	Approx. Commuter En- planements
1	Ephrata Wenatchee		1.0%	92.0%	.392%	189,666,700	6,800	800 ⁽²⁾			7,000
2	Hoquiam Olympia		4.0%	8.0%	.392%	189,666,700	2,400	100 ⁽²⁾			23,000
3	Pasco		10.5%	92.0%	.392%	189,666,700	71,800	67,100 ⁽²⁾	1.07	+ 7%	12,000
4	Pullman		4.0%	92.0%	.392%	189,666,700	27,400	8,500 ⁽²⁾			18,000
5	Seattle		--	--	--	--	--	--			
6	Spokane		82.5%	92.0%	.392%	189,666,700	564,300	649,000 ⁽³⁾	.87	-13%	20,000
7	Walla Walla		2.0%	92.0%	.392%	189,666,700	13,700	5,400 ⁽²⁾			12,000
8	Yakima		96.0%	8.0%	.392%	189,666,700	57,100	59,100 ⁽²⁾	.97	- 3%	12,000
1							743,500	790,000 ⁽²⁾			

FOOTNOTES:

(1) Enplanements are Scheduled Domestic Enplanements for Certificated Air Carriers
Source: Airport Activity Statistics, 12 Months Ending 31 Dec. 1974

(2) Does not include significant Commuter Airline Enplanements

(3) World's Fair held in Spokane in 1974. Spokane 1975 Enplanements ~550,000

TABLE 3b:

i	Airport	Code	M_i/V_a	$M_{Va}/U.S.$	1974 $E_{U.S.}$	1974 E_i	Actual En- planements 1974	$\frac{E_i}{\text{Actual}}$	$\frac{E_i}{\text{Actual}} - 1.00$
1	Charlottesville	CHO	2.4%	.98%	189,666,700	44,600	52,900	.84	-16%
2	Danville	DAN	0.3%	.98%	189,666,700	5,600	7,000	.80	-20%
3	Hot Springs	HSP	0.2%	.98%	189,666,700	3,700	4,800	.77	-23%
4	Lynchburg	LYH	3.2%	.98%	189,666,700	59,500	56,000	1.06	+ 6%
5	Newport News	PHF	11.9%	.98%	189,666,700	221,200	200,500	1.10	+10%
6	Norfolk	ORF	37.2%	.98%	189,666,700	691,400	701,500	.99	- 1%
7	Richmond	RIC	22.6%	.98%	189,666,700	420,100	426,500	.98	- 2%
8	Roanoke	ROA	18.6%	.98%	189,666,700	345,700	351,200	.98	- 2%
9	Staunton (Shed. Valley)	SHD	1.1%	.98%	189,666,700	20,400	21,900	.93	- 7%
Σ						1,812,200	1,772,100	1.02	+ 2%

TABLE 3c:

					1974 E _i U.S.	1974 E _i	Actual En- planements 1974	$\frac{E_i}{\text{Actual}}$	$\frac{E_i}{\text{Actual}}$ -1.00
1	Airport	Code	M _i /Ore	M _{Ore} /U.S.					
1	Astoria	AST	--	.16%	189,666,700	--	700	--	--
2	Eugene	EUG	45.0%	.16%	189,666,700	136,600	136,100	1.00	0%
3	Klamath Falls	LMT	5.0%	.16%	189,666,700	15,200	24,500	.62	-38%
4	Medford	MFR	31.0%	.16%	189,666,700	94,100	93,900	1.00	0%
5	North Bend	OTH	3.0%	.16%	189,666,700	9,100	15,500	.59	-41%
6	Pendleton	PDT	11.0%	.16%	189,666,700	33,400	28,200	1.18	+18%
7	Portland	PDX	--			--	--	--	--
8	Redmond	RDM	2.0%	.16%	189,666,700	6,100	7,600	.80	-20%
9	Salem	SLE	3.0%	.16%	189,666,700	9,100	13,200	.69	-31%
Σ						303,600	319,700	.95	- 5%

TABLE 4a
Values of Mode Specific Calibration Parameters

<u>Mode</u>	<u>a_m</u>	<u>$\alpha_m(1)$</u>	<u>$\alpha_m(2)$</u>	<u>$\alpha_m(3)$</u>
Auto	13.76	- 1.6	- 1.6	0
Bus	1.50	- 1.5	- 1.5	0.3247
Air (except Chicago-Detroit)	1.50	- 1.5	- 1.5	0.3247
Air (Chicago-Detroit only)	0.75	- 1.5	- 1.5	0.3247

TABLE 4b

	<u>Air</u>	<u>Auto</u>	<u>Bus</u>
Charlottesville-Roanoke			
Distance (mi.)	100	115	115
Time (hrs.)	1.7	2.3	3.0
Cost (1974 \$)	30.50	6.00	7.50
Cost (1970 \$)	20.90	4.10	5.15
Frequency (per day)	1	∞	3
w_m	3.49×10^{-3}	.380	.017
$W = .40$			
$W^{0.1} = .91$			
Charlottesville-Dallas			
Distance (mi.)	1,100	1,250	
Time (hrs.)	7.25	38	
Cost (1974 \$)	142	75	
Cost (1970 \$)	97	52	
Frequency (per day)	4	∞	
w_m	5.88×10^{-5}	7.33×10^{-5}	$w_{bus} < 10^{-5}$
$W = 1.32 \times 10^{-4}$			
$W^{0.1} = .41$			
Charlottesville-San Francisco			
Distance (mi.)	2,400	3,000	
Time (hrs.)	10.75	110	
Cost (1974 \$)	220	220	
Cost (1970 \$)	150	150	
Frequency (per day)	4	∞	
w_m	9.54×10^{-6}	2.46×10^{-6}	$w_{bus} < 10^{-6}$
$W = 1.20 \times 10^{-5}$			
$W^{0.1} = .32$			

Notes: Air time = flight time + 45 min. check-in + 15 min. egress at arrival + 1 hour ground time to and from airports (check-in and egress shortened for Charlottesville-Roanoke because it is assumed no checked baggage for short flight)

Air Cost = flight cost + \$1 for gas for car driven to and from Charlottesville Airport (assume no parking) + \$2.50 for taxi at destination

Auto time = calculated at 50 mph while on road, or maximum of 600 mi/day

Auto Cost = calculated at 15 mpg and \$.60/ga. Food cost estimated at \$3/meal and hotel at \$15/night.

TABLE 4c

Travel Region, Gateway Cities, and Values of Regional Constants

<u>Regions within Michigan</u>	<u>Gateway City</u>	<u>Value of Region Constant (multiplied by 10³)</u>
1	Detroit	10.38
2	Jackson	2.00
3	Kalamazoo	5.20
4	Benton Harbor	2.42
5	Flint	3.24
6	Lansing	8.66
7	Saginaw	7.22
8	Grand Rapids	8.43
9	Alpena	6.65
10	Traverse City	16.97
11	Sault Saine Marie	27.20
12	Escanaba	36.38
13	Marquette	30.50
14	Houghton (Hancock)	47.70
15	¹ Port Huron	8.94
16	¹ Pontiac	10.75
17	¹ Ann Arbor	10.60
18	¹ Monroe	4.57
19	Battle Creek	5.50
20	¹ Caro	4.14
21	Muskegon	10.30
22	¹ Bay City	7.92
23	¹ Ludington	5.20
24	Pellston	40.00
25	Menominee	37.02
26	Iron Mountain	40.00
27	Ironwood	39.48

¹These regions do not have their own airport.

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TABLE 4c (cont'd)

<u>Regions Outside Michigan</u>	<u>Gateway City</u>	<u>Value of Region Constant (Multiplied by 10⁴)</u>
28	Green Bay	5.62
29	Milwaukee	10.04
30	Chicago	9.34
31	South Bend	3.53
32	Toledo	2.26
33	Cleveland	2.48
34	Pittsburgh	3.44
35	Buffalo	5.50
36	Minneapolis	11.02
37	Des Moines	4.39
38	St. Louis	11.68
39	Indianapolis	5.89
40	Louisville	12.15
41	Cincinnati	4.99
42	Columbus	3.47
43	Billings	6.67
44	Denver	40.52
45	Kansas City	9.09
46	Dallas	10.21
47	Birmingham	2.05
48	Atlanta	3.95
49	Washington, D.C.	10.06
50	Philadelphia	9.12
51	New York	13.09
52	Seattle	56.32
53	San Francisco	73.75
54	Los Angeles	77.90
55	Miami	119.69
56	Boston	12.65

TABLE 4d Data for Michigan Model (Travel to Grand Rapids)

j	Gateway	B_j	P_j	C_{air}	t_{air}	f_{air}	d	$W^{0.1}$	W_{air}	T_{air}	one-way		*
											t_j	$\frac{1}{2}$	
1	Detroit	10.38×10^{-4}	2,560,000	4,736,000	21.00	2.7	6	126	.88	2.8×10^{-3}	9,530	11,205	22,410
2	Jackson	2.00	272,100			0				--			
3	Kalamazoo	5.20	292,800	467,000		0				--			
4	Benton Harbor	2.42	275,200		20.00	2.2	4	69	.92	3.76×10^{-3}	170	125	250
5	Flint	3.24	290,600			0				--			
6	Lansing	8.66	396,500		17.00	2.1	5	48	.93	5.43×10^{-3}	1,220	130	260
7	Saginaw	7.22	383,000	690,600	18.00	2.2	1	86	.91	2.97×10^{-3}	990	425	850
8	Grand Rapids	8.43	722,600							--			
9	Alpena	6.65	107,800			0				--			
10	Traverse City	16.97	140,400		24.00	2.2	1	129	.88	1.93×10^{-3}	320	620	1,240
11	Sault St. Marie	27.20	53,500			0				--			
12	Escanaba	36.38	46,700		34.00	3.8	3	211	.81	6.93×10^{-4}	90	655	1,310
13	Marquette	30.50	79,100		36.00	4.1	2	271	.78	5.29×10^{-4}	100	1,190	2,380
14	Hancock	47.70	46,500		40.00	4.8	1	330	.74	2.78×10^{-4}	50	685	1,370
15	Port Huron (Detroit)		745,500	} add to Detroit									
16	Pontiac (Detroit)		966,800										
17	Ann Arbor (Detroit)		234,100										
18	Monroe (Detroit)		119,200										
19	Battle Creek (Kalamazoo)		179,900										
20	Garo (Saginaw)												
21	Muskegon	10.30	241,100	274,500	17.00	2.1	1	41	.94	3.47×10^{-3}	640	45	90
22	Bay City Saginaw												
23	Ludington (Muskegon)												
24	Pellston	40.00	38,900			0				--			
25	Menominee	37.02	25,000		28.00	2.2	2			1.96×10^{-3}			
26	Iron Mountain	40.00	38,400			0				--			
27	Ironwood	39.48	31,700			0				--			
28	Green Bay	5.62	795,000		26.00	2.6	3	171	.85	1.83×10^{-3}	590	3,190	6,380
29	Milwaukee	10.04	3,624,000		20.00	2.6	4	120	.88	2.92×10^{-3}	7,350	8,690	17,380
30	Chicago	9.34	11,587,000		21.00	2.4	12	134	.87	3.84×10^{-3}	29,100	35,495	70,990
31	South Bend	3.55	964,000		22.00	2.3	1	91	.91	2.05×10^{-3}	470	160	320
32	Toledo	2.26	1,079,000		23.00	2.3	1	125	.88	1.92×10^{-3}	320	440	880
33	Cleveland	2.48	3,426,000		26.00	2.7	5	216	.82	1.97×10^{-3}	1,240	9,845	19,690
34	Pittsburgh	3.44	5,418,000		33.00	4.2	5	319	.76	7.10×10^{-4}	1,060	3,855	7,710
35	Buffalo	5.50	2,556,000		45.00	4.5	4	344	.74	3.81×10^{-4}	440	1,345	2,690

* Travel between gateway airports (both ways) based upon 10% ticket returns to CAB 1 Apr 1972 to 31 Mar. 1973.

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TABLE 4d (cont'd)

i	Gateway	B _i	P _i	C _{air}	t _{air}	f _{air}	d	W ^{0.1}	W _{air}	T _{air i}	one-way	*
											$\frac{1}{2}$	
36	Minneapolis	11.02	5,369,000	53.00	4.5	15	408	.70	3.84×10^{-4}	1,980	7,410	14,820
37	Des Moines	4.39	2,571,000	50.00	4.5	11	428	.69	4.02×10^{-4}	400	1,015	2,030
38	St. Louis	11.68	2,915,000	46.00	4.2	10	382	.71	4.97×10^{-4}	1,450	3,020	6,040
39	Indianapolis	5.89	3,701,000	40.00	4.1	11	221	.81	6.46×10^{-4}	1,060	1,685	3,370
40	Louisville	12.15	3,019,000	50.00	4.1	6	325	.75	4.12×10^{-4}	1,230	2,105	4,210
41	Cincinnati	4.99	3,126,000	46.00	4.3	11	268	.78	4.87×10^{-4}	590	1,980	3,960
42	Columbus	3.47	3,449,000	40.00	4.0	2	242	.80	4.69×10^{-5}	430	1,545	3,090
43	Billings	6.67	1,895,000	94.00	7.8	2	1,154	.40	4.78×10^{-5}	90	135	270
44	Denver	40.52	7,547,000	86.00	6.6	8	1,027	.42	9.48×10^{-5}	4,200	3,295	6,590
45	Kansas City	9.09	6,171,000	55.00	4.9	10	540	.63	3.02×10^{-4}	1,640	2,475	4,950
46	Dallas	10.21	20,528,000	79.00	5.9	14	927	.45	1.39×10^{-4}	3,940	2,605	5,210
47	Birmingham	2.05	10,358,000	66.00	4.3	3	646	.57	2.13×10^{-4}	480	520	1,040
48	Atlanta	3.95	13,727,000	67.00	5.1	11	640	.57	2.15×10^{-4}	1,250	3,000	6,000
49	Washington	10.06	9,720,000	45.00	3.8	2	513	.34	4.24×10^{-4}	3,950	6,730	13,460
50	Philadelphia	9.12	10,981,000	58.00	4.3	7	576	.61	3.17×10^{-4}	3,170	5,155	10,310
51	New York	13.09	23,756,000	50.00	4.3	3	614	.58	3.23×10^{-4}	10,550	22,155	44,310
52	Seattle	56.32	5,749,000	131.00	8.3	5	1,807	.32	3.23×10^{-5}	1,990	1,885	3,770
53	San Francisco	73.75	7,350,000	131.00	7.6	12	1,964	.32	4.37×10^{-5}	4,510	3,790	7,580
54	Los Angeles	77.90	13,526,000	131.00	7.8	14	1,863	.33	4.29×10^{-5}	8,340	7,110	14,220
55	Miami	119.69	7,099,000	101.00	6.5	12	1,215	.38	8.17×10^{-5}	11,130	4,045	8,090
56	Boston	12.65	9,062,000	70.00	4.8	8	740	.54	2.08×10^{-4}	2,690	4,890	9,780

* Travel between gateway airports (both ways) based upon 10% ticket returns to CAB 1 Apr 1972 to Mar. 1973.

TABLE 5

Variable \ Author	Billheimer	Goodknight	Judycki, et al.	Kanafani & Fan	Kraft & Kraft	Navin & Wolsfeld	Su	Yu	Jacobson & Kuhlthau	PAA
Time	X		X	X	X			X	X	
Cost	X			X	X			X	X	
Departures/day	X			X				X	X	
Attractiveness		X						X		
Taxable Payroll		X								
Population		X		X			X	X		
Hotel & Motel Payroll		X								
No. of Registered Autos			X					X		
Income			X	X		X	X			
Demand Deposits			X					X		
No. of College Students			X					X		
Employment in Gov't.			X			X				X
Comfort					X				X	
Convenience					X		X		X	
No. of hotel/motel rooms						X				
Emp. in Wholesal/Man.						X		X		X
Emp. in Finance/Ins./Real Estate						X				X
Emp. in Retail						X				X
No. of dwelling units						X				
Distance							X			
Property Value								X		
Sales Tax								X		
Safety									X	
Reliability									X	
Abil. to Work									X	

TABLE 7

List of Factors Considered Important to Air Travel Demand

MODE VARIABLES

Comfort
Convenience
Cost
Reliability
Safety
Service
Speed

PERSONAL VARIABLES

Age
Education
Income
Occupation
Car Ownership

REGIONAL VARIABLES

Employment
Industrial Characteristics
Population

TRIP VARIABLES

Length of Stay
Number of persons traveling
in party
Number of stops in travel itinerary
Purpose of Trip
Travel Time (or Distance)

TABLE 8

Selected Cities

<u>IOWA</u>	<u>MINNESOTA</u>
1. Des Moines (DSM)	16. Bemidji (BJI)
2. Fort Dodge (FOD)	17. Brainerd (BRD)
3. Burlington (BRL)	18. Hibbing (HIB)
4. Keokuk (EOK)	19. Eveleth (EVM)
5. Marshalltown (MIW)	20. Fairmont (FRM)
6. Cedar Rapids (CID)	21. Grand Rapids (GPZ)
7. Mason City (MCW)	22. International Falls (INL)
8. Ottumwo (OTM)	23. Mankato (MKT)
9. Spencer (SPW)	24. New Ulm (ULM)
10. Waterloo (ALO)	25. Thief River Falls (TVF)
11. Clinton (CWI)	26. Winona (ONA)
12. Dubque (DBQ)	27. Worthington (OTG)
13. Davenport (DVN)	28. Duluth (DLH)
14. Fort Madison (QTM)	29. Rochester (RST)
15. Sioux City (SUX)	30. Minneapolis-St. Paul (MSP)

TABLE 8 (cont'd)

MISSOURI

- 31. Cape Girardeau (CGI)
- 32. Jefferson City (JEF)
- 33. Joplin (JLN)
- 34. Kirksville (IRK)
- 35. Rolla (RLA)
- 36. Springfield (SGF)
- 37. Columbia (COU)
- 38. St. Louis (STL)
- 39. Sedalie (DMO)
- 40. Malden (MAW)
- 41. Kansas City (MCI)
- 42. Poplar Bluff (POF)
- 43. Ft. Leonard Wood (TBN)

NEBRASKA

- 44. Alliance (AIA)
- 45. Chadron (CDR)
- 46. Columbus (OLU)
- 47. Grand Island (GRI)
- 48. Hastings (HSI)
- 49. Kearney (EAR)
- 50. McCook (MCK)
- 51. Norfolk (OFK)
- 52. North Platte (LBF)
- 53. Scottsbluff (BFF)
- 54. Sidney (SNY)
- 55. Lincoln (LNK)
- 56. Omaha (OMA)

TABLE 8 (cont'd)

ILLINOIS

- 57. Carbondale (MDH)
- 58. Danville (DNV)
- 59. Galesburg (GBG)
- 60. Jacksonville (IJX)
- 61. Macomb (MQB)
- 62. Mattoon (MTO)
- 63. Mount Vernon (MNV)
- 64. Quincy (UIN)
- 65. Sterling/Rock Falls (SQI)
- 66. Bloomington (BMI)
- 67. Chicago (CHI)
- 68. Champaign (CMI)
- 69. Decatur (DEC)
- 70. Centralia (ENL)
- 71. Moline (MLI)
- 72. Peoria (PIA)
- 73. Rockford (RFD)
- 74. Springfield (SPI)

KANSAS

- 75. Dodge City (DDC)
- 76. Garden City (GCK)
- 77. Goodland (GLD)
- 78. Great Bend (GBD)
- 79. Hays (HYS)
- 80. Hutchison (HUT)
- 81. Lawrence (LWC)
- 82. Liberal (LBL)
- 83. Manhattan (MHK)
- 84. Olathe (OJC)
- 85. Salina (SLN)
- 86. Wichita (ICT)
- 87. Parsons (PPF)
- 88. Topeka (TPO)

TABLE 8 (cont'd)

VIRGINIA

- 89. Lynchburg (LYH)
- 90. Newport News (PHF)
- 91. Norfolk (ORF)
- 92. Richmond (RIC)
- 93. Roanoke (ROA)
- 94. Charlottesville (CHO)
- 95. Danville (DAN)
- 96. Hot Springs (HSP)
- 97. Manassas (MNS)
- 98. Pulaski (PSK)
- 99. Staunton (SHD)

MICHIGAN

- 100. Detroit (DTW)
- 101. Grand Rapids (GRR)
- 102. Flint (FNT)
- 103. Lansing (LAN)
- 104. Muskegon (MKG)
- 105. Saginaw (MBS)
- 106. Alpena (APN)
- 107. Kalamazoo (AZ)
- 108. Benton Harbor (BEH)
- 109. Battle Creek (BTL)
- 110. Hancock (CMX)
- 111. Escanaba (ESC)
- 112. Iron Mountain (IMT)
- 113. Iron Wood (IWD)
- 114. Jackson (JXN)
- 115. Manistee (MBL)
- 116. Menominee (MNM)
- 117. Marquette (MQT)
- 118. Pellston (PLN)
- 119. Sault Ste Marie (SSM)
- 120. Traverse City (TVC)

OREGON

- 121. Eugene (EUG)
- 122. Portland (PDX)
- 123. Washington, D.C.
- 124. New York, N. Y.

TABLE 9
Selected City Pairs with 1974 Data

	City pairs i to j	No. of Passengers T_{ij} in thousands	Attractiveness Road condition	Distance miles	Population i in thousands	Population j in thousands	# of flights	# of seats
1	DSM-WAS	11.548	10 10	890	574	2990	6	479
2	CID-WAS	5.575	8 6	793	300	2990	4.1	244
3	RST-WAS	2.840	5 4	867	250	2990	4.3	260
4	MSP-WAS	65.682	18 10	923	2,362	2990	16.1	1427
5	CHI-WAS	243.002	20 10	595	7,013	2990	32.6	3988
6	CMI-WAS	8.262	10 10	595	183	2990	5.0	358
7	MLI-WAS	7.385	6 9	730	220	2990	5.4	365
8	PIA-WAS	5.995	10 8	677	439	2990	6.0	372
9	SPI-WAS	4.262	10 8	673	253	2990	4.0	219
10	ICT-WAS	8.300	15 10	1103	529	2990	3.6	278
11	STL-WAS	68.227	18 10	707	2,439	2990	6.5	680
12	MCI-WAS	42.375	12 10	940	1,633	2990	7.5	708
13	LNK-WAS	4.570	10 8	1048	319	2990	2.3	111
14	OMA-WAS	15.507	14 10	1004	803	2990	4.6	407
15	DAN-WAS	1.470	3 2	199	264	2990	1.8	102
16	SHD-WAS	2.730	3 7	100	201	2990	3.5	198
17	DSM-NYC	19.442	10 10	1027	574	17,224	9.25	704
18	DLH-NYC	4.782	10 5	1001	211	17,224	3.2	203
19	RST-NYC	6.537	5 4	973	250	17,224	5.6	523
20	MSP-NYC	134.390	18 10	1018	2,362	17,224	17.4	1732
21	STL-NYC	165.177	18 10	883	2,439	17,224	17.2	1956
22	MCI-NYC	83.495	12 10	1101	1,633	17,224	15.0	1386
23	LNK-NYC	6.150	10 8	1193	319	17,224	4.2	265
24	OMA-NYC	27.325	14 10	1144	803	17,224	8.7	770
25	PIA-NYC	10.790	10 8	824	439	17,224	8	495
26	SPI-NYC	4.782	10 8	832	253	17,224	6.7	361
27	CMI-NYC	9.932	10 10	756	183	17,224	5.7	314
28	CHI-NYC	854.6	20 10	722	7,013	17,224	62.2	9807
29	ICT-NYC	15.195	15 10	1279	529	17,224	7	593
30	SHD-NYC	2.490	3 7	313	201	17,224	2.75	114
31	CWI-CHI	0.762	3 6	132	79	7,013	2	96
32	DSM-CHI	62.932	10 10	306	574	7,013	10	1177
33	DBQ-CHI	5.01	8 2	156	148	7,013	5+	271

TABLE 9 (cont'd)

	City pairs i to j	No. of Passengers T_{ij} in thousands	Attractiveness Road condition	Distance miles	Population i in thousands	Population j in thousands	# of flights	# of seats
34	FOD-CHI	1.790	3 5	333	170	7,013	1	32
35	BRL-CHI	4.957	3 4	191	74	7,013	2	96
36	CID-CHI	26.620	8 6	204	300	7,013	6.2	643
37	MCW-CHI	5.167	3 5	298	165	7,013	1.8	84
38	OTM-CHI	1.305	3 3	249	115	7,013	.66	24
39	SUX-CHI	11.570	6 8	445	225	7,013	4.0	394
40	ALO-CHI	14.377	3 3	243	274	7,013	3.83	347
41	DLH-CHI	14.747	10 5	407	211	7,013	3.25	254
42	INL-CHI	3.335	10 1	538	215	7,013	1.1	75
43	MSP-CHI	262.917	18 10	345	2,362	7,013	32.5	5144
44	RST-CHI	25.525	5 4	279	250	7,013	7.25	682
45	ONA-CHI	.0075	3 4	251	63	7,013	1	15
46	HIB-CHI	2.142	3 4	456	113	7,013	1.4	56
47	CGI-CHI	1.342	3 8	335	172	7,013	0.3	12
48	JLN-CHI	4.517	3 5	486	164	7,013	2.58	162
49	SGF-CHI	11.375	12 5	439	401	7,013	2.33	234
50	STL-CHI	220.28	18 10	256	2,439	7,013	29	2664
51	MCJ-CHI	144.47	12 10	407	1,633	7,013	18.3	2283
52	TBN-CHI	0.905	3 4	368	100	7,013	1.2	46
53	COU-CHI	5.702	3 8	320	266	7,013	1.25	82
54	LNK-CHI	14.777	10 8	473	319	7,013	3.4	301
55	OMA-CHI	62.117	14 10	423	803	7,013	8.5	1191
56	MDH-CHI	0.352	3 8	293	258	7,013	1	33
57	DNV-CHI	1.262	3 9	116	118	7,013	4	60
58	DEC-CHI	7.235	10 8	152	262	7,013	3	199
59	GBG-CHI	1.530	3 8	153	108	7,013	2	96
60	MLI-CHI	30.720	6 9	146	220	7,013	8	815
61	MTO-CHI	1.195	3 8	168	105	7,013	1	48
62	MVN-CHI	2.575	3 7	252	151	7,013	.66	24
63	PIA-CHI	24.752	10 8	131	439	7,013	8.5	676
64	UTN-CHI	5.885	3 3	224	96	7,013	2.6	94
65	SPI-CHI	11.705	10 8	173	253	7,013	11.5	595
66	SQI-CHI	0.357	3 5	100	118	7,013	2	96

ORIGINAL PAGE IS
OF POOR QUALITY

ORIGINAL PAGE IS
OF POOR QUALITY

TABLE 9 (cont'd)

ORIGINAL PAGE 18
DE POOR QUALITY

		No. of Passengers	Attractiveness Road condition	Distance miles	Population i in thousands	Population j in thousands	# of flights	# of seats
	City pairs i to j	T_{ij} in thousands						
67	BMI-CHI	2,237	7 9	114	56	7,013	4	60
68	CMH-CHI	12,102	10 10	130	183	7,013	6	372
69	ICT-CHI	27,405	15 10	591	529	7,013	7	798
70	ORF-CHI	23,610	12 8	707	824	7,013	7	682
71	KIC-CHI	17,640	18 9	632	935	7,013	5.8	516
72	ROA-CHI	11,192	5 6	520	393	7,013	1	101
73	BTL-CHI	0.0175	10 8	132	181	7,013	6	155
74	BEH-CHI	4,322	8 9	71	275	7,013	5	280
75	FNT-CHI	14,290	15 10	219	551	7,013	4.7	395
76	GRR-CHI	35,685	15 9	134	762	7,013	11.8	1128
77	GMX-CHI	2,562	3 1	367	39	7,013	.92	54
78	INT-CHI	2,605	3 1	273	38	7,013	1.5	100
79	IWD-CHI	1,920	3 1	350	32	7,013	.833	35
80	JXN-CHI	2,750	3 9	171	272	7,013	1	56
81	LAN-CHI	20,290	15 9	174	540	7,013	4.83	399
82	MBL-CHI	0,910	3 2	182	112	7,013	.83	42
83	MQT-CHI	4,287	3 1	322	87	7,013	.83	57
84	MKG-CHI	11,920	5 9	118	241	7,013	4	314
85	PLN-CHI	4,322	3 8	295	85	7,013	3	149
86	SSM-CHI	2,077	8 8	360	54	7,013	.5	14
87	MBS-CHI	23,692	10 8	219	641	7,013	5	540
88	TVC-CHI	9,497	3 3	226	97	7,013	3	286
89	PDX-CHI	32,322	15 9	1749	1182	7,013	10.1	2105
90	MSP-DTW	48,722	18 10	534	2362	4,828	10	1571
91	RST-DTW	3,402	5 4	484	250	4,828	4	292
92	MCI-DTW	27,127	12 10	639	1633	4,828	6.25	551
93	STL-DTW	55,495	15 10	451	2439	4,828	9.4	965
94	LNK-DTW	1,732	10 8	710	319	4,828	.8	61
95	OMA-DTW	7,012	14 10	660	803	4,828	4	290
96	CHI-DTW	276,71	20 10	237	7013	4,828	10.6	5281
97	APN-DTW	2,295	3 3	192	96	4,828	1.5	84
98	ESC-DTW	1,720	3 1	305	47	4,828	1	57

TABLE 9 (cont'd)

	City pairs i to j	No. of Passengers T_{ij} in thousands	Attractiveness Road condition	Distance miles	Population i in thousands	Population j in thousands	# of flights	# of seats
99	CMX-DTW	3.330	3 1	425	39	4,828	1.5	46
100	JKN-DTW	0.322	3 9	66	272	4,828	3	168
101	MQT-DTW	4.385	3 1	363	87	4,828	1.8	71
102	PLN-DTW	2.887	3 8	239	85	4,828	2.9	136
103	SSM-DTW	2.147	8 8	294	54	4,828	1.2	56
104	TVC-DTW	8.212	3 3	207	97	4,828	4	240
105	CID-SUX	1.140	8 6	243	300	225	.5	57
106	DSM-SUX	2.720	10 10	153	574	225	2	200
107	ALO-SUX	0.902	3 3	204	274	225	1.5	172
108	DLH-SUX	0.140	10 5	370	211	225	.33	29
109	FRM-SUX	0.0075	3 8	131	40	225	.66	28
110	OMA-SUX	0.357	14 10	80	803	225	3	112
111	CID-MCI	5.265	8 6	241	300	1,633	2	129
112	DSM-MCI	17.602	10 10	169	574	1,633	7	558
113	OTM-MCI	0.632	3 3	176	115	1,633	2	96
114	SUX-MCI	4.470	6 8	238	225	1,633	3	227
115	ALO-MCI	2.250	3 3	260	274	1,633	1	48
116	DLH-MCI	1.037	10 5	542	211	1,633	.3	29
117	FRM-MCI	0.105	3 8	307	40	1,633	.3	14
118	MSP-MCI	42.330	18 10	399	2,362	1,633	7	797
119	RST-MCI	2.360	5 4	343	250	1,633	.6	24
120	COU-MCI	1.292	3 8	138	266	1,633	4	116
121	JLN-MCI	2.110	3 5	142	164	1,633	3	168
122	STL-MCI	76.655	18 10	233	2,439	1,633	17	1842
123	SGF-MCI	7.315	12 5	152	401	1,633	3.5	210
124	OLU-MCI	0.231	3 3	210	74	1,633	1	56
125	GRI-MCI	1.585	3 5	228	108	1,633	1.7	78
126	HSI-MCI	0.210	3 4	222	51	1,633	.3	14
127	LNK-MCI	3.112	10 8	159	319	1,633	3	197
128	LEF-MCI	0.907	5 8	346	86	1,633	1	42
129	OMA-MCI	30.610	14 10	158	803	1,633	9	849
130	BFF-MCI	0.785	3 3	505	36	1,633	1	42

TABLE 9 (cont'd)

		No. of Passengers		Attractiveness Road condition	Distance miles	Population i in thousands	Population j in thousands	# of flights	# of seats
City pairs i to j	T _{ij} in thousands								
131	GCK-MCI	0.617	2	2	340	41	1,633	1	16
132	GLD-MCI	0.222	2	7	377	39	1,633	.3	14
133	GBD-MCI	0.015	2	4	235	53	1,633	1	15
134	HYS-MCI	0.787	2	6	250	78	1,633	1	25
135	MHK-MCI	1.787	2	7	108	152	1,633	7	231
136	SLN-MCI	1.337	10	9	164	137	1,633	1.5	71
137	ICT-MCI	19.332	15	10	185	529	1,633	11	1196
138	MLI-MCI	6.055	6	9	270	220	1,633	1.53	69
139	PIA-MCI	3.685	10	8	282	439	1,633	2.75	162
140	SPI-MCI	1.410	10	8	270	253	1,633	1	90
141	PDX-MCI	8.675	15	9	1487	1182	1,633	4.2	214
142	CID-MSP	10.54	8	6	221	300	2,362	2	230
143	DSM-MSP	26.66	10	10	232	574	2,362	6.6	691
144	SUX-MSP	5.085	6	8	234	225	2,362	1.6	113
145	ALO-MSP	4.305	3	3	166	274	2,362	3	278
146	BJI-MSP	4.282	3	1	199	56	2,362	1.5	84
147	DLH-MSP	15.732	10	5	144	211	2,362	6	572
148	FRM-MSP	0.735	3	8	104	40	2,362	1	56
149	HIB-MSP	4.302	3	4	174	113	2,362	3	168
150	INL-MSP	3.720	10	1	254	22	2,362	1.6	84
151	STL-MSP	47.152	18	10	448	2439	2,362	10	905
152	OMA-MSP	38.69	14	10	282	803	2,362	8.3	930
153	ICT-MSP	5.637	15	10	545	529	2,362	1.5	119
154	MLI-MSP	11.840	6	9	268	220	2,362	1.3	144
155	PIA-MSP	5.065	10	8	342	439	2,362	1.5	236
156	AZO-MSP	4.305	8	8	166	252	2,362	2.5	100
157	OFK-MSP	0.835	2	3	292	120	2,362	.3	14
158	PDX-MSP	17.577	15	9	1426	1182	2,362	3	427
159	LBF-LNK	0.740	5	8	207	86	319	1	56
160	BRL-STL	1.520	3	4	146	74	2,439	1.5	72
161	CID-STL	4.720	8	6	228	300	2,439	1.8	201
162	DSM-STL	17.452	10	10	259	574	2,439	6.8	680
163	ALO-STL	1.907	3	3	284	274	2,439	.6	40
164	CGI-STL	1.312	3	8	114	172	2,439	3	126

ORIGINAL PAGE IS
OF POOR QUALITY

TABLE 9 (cont'd)

	City pairs i to j	No. of Passengers T_{ij} in thousands	Attractiveness Head condition	Distance miles	Population i in thousands	Population j in thousands	# of flights	# of seats
165	TBN-STL	1.290	3 4	119	100	2,439	5	229
166	JLN-STL	4.325	3 5	251	164	2,439	2.3	217
167	IRK-STL	0.290	3 2	149	135	2,439	.5	24
168	SGF-STL	9.345	12 5	195	401	2,439	5.5	557
169	CMI-STL	3.120	10 10	143	183	2,439	2.8	216
170	MTO-STL	9.220	3 8	123	105	2,439	1	48
171	MLI-STL	9.635	6 9	192	220	2,439	3.5	345
172	MVN-STL	0.380	3 7	87	151	2,439	2	96
173	PIA-STL	6.737	10 8	137	439	2,439	5	474
174	UIN-STL	1.397	3 3	94	96	2,439	5.5	244
175	XFD-STL	0.562	3 9	247	455	2,439	.5	24
176	SPI-STL	2.945	10 8	84	253	2,439	8	585
177	SQI-STL	0.097	3 5	210	118	2,439	.3	12
178	LNK-STL	3.452	10 8	370	319	2,439	2.5	185
179	OMA-STL	19.435	14 10	342	803	2,439	7.2	640
180	MHK-STL	0.792	2 7	341	152	2,439	.5	28
181	SLN-STL	0.372	10 9	393	137	2,439	.3	14
182	ICT-STL	12.037	15 10	392	529	2,439	5	365
183	PDX-STL	8.187	15 9	1708	1182	2,439	6.6	496
184	RST-STL	2.117	5 4	373	250	2,439	1.3	139
185	TOP-ICT	0.227	8 10	138	287	529	2	112
186	OMA-ICT	3.057	14 10	265	803	529	2.1	127
187	CID-OMA	2.075	8 6	221	300	803	2	198
188	DSM-OMA	4.272	10 10	117	574	803	2	228
189	DBQ-OMA	0.670	8 2	278	148	803	.83	36
190	FOD-OMA	0.442	3 5	123	170	803	1	48
191	MCI-OMA	0.797	3 5	184	165	803	.5	24
192	OTH-OMA	0.015	3 3	180	115	803	.06	14
193	OLU-OMA	0.125	3 3	76	74	803	2	112
194	GRI-OMA	1.172	3 5	128	108	803	2	141
195	HST-OMA	0.172	3 4	141	51	803	.33	14
196	EAR-OMA	0.322	3 3	167	25	803	.33	14
197	MCK-OMA	0.262	2 3	258	38	803	.33	14
198	OFK-OMA	0.677	2 3	93	120	803	2	112
199	LBK-OMA	2.177	5 8	251	86	803	.6	28

TABLE 9 (cont'd)

	City pairs i to j	No. of Passengers T_{ij} in thousands	Attractiveness Road condition	Distance miles	Population i in thousands	Population j in thousands	% of flights	# of seats
200	LNK-OMA	0.465	10 8	55	319	803	7	652
201	DLH-OMA	1.612	10 5	425	211	803	1	66
202	FRM-OMA	0.037	3 8	178	40	803	.33	14
203	HIB-OMA	0.145	3 4	447	113	803	.53	14
204	MKT-OMA	0.102	3 5	225	162	803	.33	14
205	JLN-OMA	0.602	3 5	296	164	803	.5	28
206	MLI-OMA	3.600	6 9	278	220	803	1.5	141
207	CID-ALO	0.085	8 6	58	300	274	2	163
208	DSM-ALO	0.835	10 10	96	574	274	3	211
209	DBQ-ALO	0.110	8 2	87	148	274	3	211
210	FOD-ALO	0.022	3 5	91	170	274	.5	24
211	MCW-ALO	0.050	3 5	63	165	274	2	96
212	MLI-ALO	1.242	6 7	120	220	274	3	311
213	RFD-ALO	0.192	3 9	171	455	274	.5	24
214	OMA-ALO	1.687	14 10	200	803	274	1.3	64
215	RST-ALO	0.322	5 4	93	250	274	3	211
216	STL-ALO	1.907	18 10	284	7439	274	1.1	107
217	CHO-WAS	5.6	10 5	84	163	2,990	3.5	198
218	LYH-WAS	5.7	4 4	152	176	2,990	3	239
219	PHF-WAS	16.4	8 9	129	364	2,990	3.5	369
220	ORF-WAS	54.4	12 8	149	824	2,990	9	778
221	ROA-WAS	24.1	5 6	184	393	2,990	9.16	513
222	DTW-WAS	101.1	20 10	391	4828	2,990	11.33	1241
223	GRR-WAS	7.4	15 9	513	762	2,990	4.16	275
224	FNT-WAS	3.4	15 10	441	551	2,990	1.33	71
225	LAN-WAS	7.9	15 9	468	540	2,990	3.92	239
226	MBS-WAS	5.4	10 8	478	641	2,990	2.5	145
227	PDY-WAS	15.8	15 9	2339	1182	2,990	4.6	538
228	LYH-ORF	0.6	4 4	168	176	824	.5	15
229	ROA-ORF	8.3	5 6	210	393	824	1.66	131
230	CHO-ROA	0.3	10 5	101	163	393	1	101

ORIGINAL PAGE IS
OF POOR QUALITY

TABLE 9 (cont'd)

City pairs i to j	No. of Passengers T _{ij} in thousands	Attractiveness Road condition		Distance miles	Population i in thousands	Population j in thousands	# of flights	# of seats
231	PHF-ROA	1.4	8 8	192	364	393	1	101
232	RIC-ROA	10.4	18 9	147	935	393	5	423
233	ORF-DTW	11.6	12 8	527	824	4,828	3.58	263
234	ROA-DTW	2.9	5 6	384	393	4,828	1.71	96
235	GRR-DTW	12.2	15 9	126	762	4,828	4	253
236	LAN-DTW	5.0	15 9	79	540	4,828	10	682
237	MKG-DTW	3.1	5 9	166	241	4,828	2	141
238	MBS-DTW	6.0	10 8	96	553	4,828	3.5	255
239	PDX-DTW	6.8	15 9	1959	1182	4,828	5.87	730
240	EUG-PDX	4.3	10 7	106	396	1,182	3	292
241	WAS-NYC	642.5	20 10	214	2990	17,224	54	5797
242	CHO-NYC	16.4	10 5	299	163	17,224	4.08	283
243	LYH-NYC	9.2	4 4	366	176	17,224	4.37	261
244	PHF-NYC	27.8	8 9	283	364	17,224	4.25	358
245	ORF-NYC	101.6	12 8	291	824	17,224	11.58	1225
246	RIC-NYC	72.0	18 9	286	935	17,224	7.2	663
247	ROA-NYC	23.9	5 6	399	393	17,224	5.08	418
248	DTW-NYC	408.6	20 10	489	4828	17,224	25.33	4195
249	GRR-NYC	24.1	15 9	614	762	17,224	7.04	548
250	MBS-NYC	14.9	10 8	553	641	17,224	4.66	341
251	PDX-NYC	32.2	15 9	2241	1182	17,224	5.71	1061

TABLE 10

Selected City Pairs with 1970 Data

	City Pairs i to j	No. of Passengers T_{ij} in thousands	Attractiveness	Road Conditions	Distance Miles	Population i in thousands	Population j in thousands	# of flights	# of seats
1	DSM-WAS	9.955	10	10	886	551	3,080	4.2	258
2	CID-WAS	5.090	8	6	789	296	3,080	2.1	137
3	RST-WAS	1.995	5	4	863	243	3,080	0.66	47
4	MSP-WAS	60.220	18	10	919	2,284	3,080	16.2	1,350
5	CHI-WAS	203.540	20	10	591	7,004	3,080	27	2,770
6	CMI-WAS	6.845	10	10	595	182	3,080	4.9	415
7	MLI-WAS	6.975	6	9	723	220	3,080	3.7	239
8	PIA-WAS	5.660	10	8	673	426	3,080	5.7	417
9	SPI-WAS	2.965	10	8	668	246	3,080	3.2	151
10	ICT-WAS	5.410	15	10	1,098	539	3,080	1.5	98
11	STL-WAS	58.995	18	10	707	2,462	3,080	10.9	970
12	MCI-WAS	36.330	12	10	932	1,602	3,080	7	551
13	LNK-WAS	3.880	10	8	1,044	306	3,080	1.8	113
14	OMA-WAS	13.165	14	10	1,000	765	3,080	4	272
15	DAN-WAS	1.345	3	2	197	257	3,080	1.2	48
16	SHD-WAS	3.445	3	7	100	187	3,080	3	180
17	DSM-NYC	19.575	10	10	1,026	551	17,865	7.5	538
18	DLH-NYC	4.140	10	5	1,001	199	17,865	4.3	328
19	RST-NYC	6.595	5	4	971	243	17,865	7.4	464
20	MSP-NYC	134.080	18	10	1,016	2,284	17,865	9.2	1,699
21	STL-NYC	170.460	18	10	882	2,462	17,865	18.2	2,082
22	MCI-NYC	86.455	12	10	1,098	1,602	17,865	10.8	1,074
23	LNK-NYC	4.880	10	8	1,192	306	17,865	4.2	267
24	OMA-NYC	28.920	14	10	1,143	765	17,865	8.5	678
25	PIA-NYC	11.885	10	8	824	426	17,865	10.3	633
26	SPI-NYC	4.575	10	8	831	246	17,865	7.4	340
27	CMI-NYC	11.210	10	10	755	182	17,865	6.8	411
28	ICT-NYC	14.370	15	10	1,273	539	17,865	7.9	521
29	SHD-NYC	2.525	3	7	313	187	17,865	1.25	63

TABLE 10 (cont'd)

	City Pairs i to j	No. of Passengers T_{ij} in thousands	Attractiveness Road Conditions		Distance Miles	Population i in thousands	Population j in thousands	# of flights	# of seats
30	CWI-CHI	1.035	3	6	132	78	7,004	2	96
31	DSM-CHI	57.510	10	10	306	551	7,004	9.8	1,025
32	DBQ-CHI	5.620	8	2	155	145	7,004	3	211
33	FOD-CHI	1.675	3	5	333	174	7,004	0.66	12
34	BRL-CHI	4.650	3	4	190	76	7,004	2	96
35	CID-CHI	25.790	8	6	203	296	7,004	7.2	703
36	MCW-CHI	5.850	3	5	298	165	7,004	1.8	118
37	OTM-CHI	1.330	3	3	249	119	7,004	0.66	24
38	SUX-CHI	12.205	6	8	444	223	7,004	3.8	353
39	ALO-CHI	13.365	3	3	242	272	7,004	3.8	415
40	DLH-CHI	14.550	10	5	407	199	7,004	5.3	359
41	INL-CHI	2.210	10	1	537	21	7,004	1.4	60
42	MSP-CHI	257.625	18	10	344	2,284	7,004	42	4,771
43	RST-CHI	24.620	5	4	278	243	7,004	7	682
44	ONA-CHI		3	4	251	62	7,004	.5	20
45	HIB-CHI	2.215	3	4	455	106	7,004	1.6	84
46	CGI-CHI	1.235	3	8	335	164	7,004	0.33	12
47	JLN-CHI	3.210	3	5	485	154	7,004	3.3	179
48	SGF-CHI	8.565	12	5	438	356	7,004	3.7	253
49	STL-CHI	211.515	18	10	256	2,462	7,004	34.6	3,372
50	MCI-CHI	142.685	12	10	407	1,602	7,004	23	2,524
51	TBN-CHI	1.685	3	4	368	105	7,004	1.8	64
52	COU-CHI	3.685	3	8	320	258	7,004	1.25	42
53	LNK-CHI	11.485	10	8	473	306	7,004	4	306
54	OMA-CHI	58.545	14	10	423	765	7,004	11.8	1,129
55	DNV-CHI	0.020	3	9	116	119	7,004	2	60
56	DEC-CHI	8.965	10	8	153	263	7,004	4	326
57	GBG-CHI	1.885	3	8	153	108	7,004	2	96
58	MLI-CHI	29.125	6	9	145	220	7,004	10	964
59	NTD-CHI	1.435	3	8	168	104	7,004	1	48

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TABLE 10 (cont'd)

	City Pairs i to j	No. of Passengers T_{ij} in thousands	Attractiveness	Road Conditions	Distance Miles	Population i in thousands	Population j in thousands	# of flights	# of seats
60	MVN-CHI	2.130	3	7	252	147	7,004	0.66	24
61	PIA-CHI	22.700	10	8	131	426	7,004	9.5	655
62	UIN-CHI	5.785	3	3	224	96	7,004	1.2	48
63	SPI-CHI	22.630	10	8	172	246	7,004	10	473
64	SQI-CHI	1.165	3	5	99	119	7,004	2	96
65	BMI-CHI	2.320	7	9	114	430	7,004	2	96
66	CMI-CHI	14.330	10	10	130	182	7,004	8	518
67	ICT-CHI	20.835	15	10	591	539	7,004	6	574
68	ORF-CHI	24.415	12	8	707	786	7,004	7.2	563
69	RIC-CHI	15.675	18	9	633	893	7,004	5.2	428
70	ROA-CHI	6.370	5	6	521	374	7,004	2	105
71	BTL-CHI	4.985	10	8	133	180	7,004	2.5	170
72	BEH-CHI	5.215	8	9	71	263	7,004	5.5	269
73	FNT-CHI	13.685	15	10	219	533	7,004	2.5	249
74	GRR-CHI	34.055	15	9	134	729	7,004	11	945
75	CMX-CHI	2.125	3	1	367	37	7,004	1.1	42
76	IMT-CHI	2.700	3	1	272	38	7,004	1.3	71
77	IWD-CHI	1.600	3	1	350	31	7,004	0.66	28
78	JKN-CHI	2.170	3	9	172	262	7,004	1	56
79	LAN-CHI	17.050	15	9	174	500	7,004	3.8	323
80	MBL-CHI	0.860	3	2	182	100	7,004	1.5	84
81	MKT-CHI	3.705	3	1	322	81	7,004	0.66	50
82	MKG-CHI	12.485	5	9	119	231	7,004	4.5	387
83	PLN-CHI	3.820	3	8	295	75	7,004	1	92
84	SSM-CHI	1.740	8	8	360	49	7,004	0.25	11
85	MBS-CHI	22.955	10	8	220	608	7,004	5.5	548
86	TVC-CHI	8.655	3	3	226	83	7,004	2.5	258
87	PDX-CHI	26.945	15	9	1,748	1,123	7,004	8.3	1,214
88	MSP-DTW	49.845	18	10	534	2,284	4,788	9	1,169
89	RST-DTW	2.870	5	4	484	243	4,788	2.6	245
90	MCI-DTW	25.380	12	10	638	1,602	4,788	7.5	593
91	STL-DTW	59.625	18	10	451	2,462	4,788	8	778

TABLE 10 (cont'd)

	City Pairs i to j	No. of Passengers T_{ij} in thousands	Attractiveness	Road Conditions	Distance Miles	Population i in thousands	Population j in thousands	# of flights	# of seats
92	OMA-DTW	6.745	14	10	660	765	4,788	1.7	108
93	CHI-DTW	256.705	20	10	238	7,004	4,788	38.5	3,669
94	APN-DTW	1.720	3	3	192	85	4,788	0.66	28
95	ESC-DTW	1.455	3	1	305	44	4,788	1.3	64
96	CMX-DTW	2.835	3	1	425	37	4,788	0.9	33
97	JXN-DTW	0.245	3	9	66	262	4,788	2	112
98	MQT-DTW	3.465	3	1	363	81	4,788	1	50
99	PLN-DTW	2.250	3	8	239	75	4,788	1.8	98
100	SSM-DTW	1.645	8	8	294	49	4,788	0.66	28
101	TVC-DTW	6.560	3	3	207	83	4,788	4.7	241
102	CID-SUX	1.335	8	6	243	296	223	0.3	23
103	DSM-SUX	1.835	10	10	152	551	223	1	90
104	ALO-SUX	0.970	3	3	204	272	223	1.5	160
105	OMA-SUX	1.195	14	10	80	765	223	3	168
106	CID-MCI	5.285	8	6	244	296	1,602	1.7	130
107	DSM-MCI	19.135	10	10	174	551	1,602	5	378
108	OTM-MCI	0.860	3	3	178	119	1,602	2	96
109	SUX-MCI	4.670	6	8	245	223	1,602	3.2	236
110	ALO-MCI	2.210	3	3	263	272	1,602	1	48
111	MSP-MCI	38.505	18	10	404	2,284	1,602	7.3	805
112	RST-MCI	2.590	5	4	348	243	1,602	0.66	24
113	COU-MCI	1.620	3	8	133	258	1,602	3.5	141
114	JLN-MCI	2.955	3	5	136	154	1,602	3	168
115	STL-MCI	80.015	18	10	229	2,462	1,602	18.8	1,853
116	SGF-MCI	9.965	12	5	146	356	1,602	3.7	310
117	HSI-MCI	0.425	3	4	228	51	1,602	0.3	14
118	LNK-MCI	8.415	10	8	165	306	1,602	5	370
119	OMA-MCI	32.520	14	10	165	765	1,602	8.5	751
120	BFF-MCI	0.845	3	3	511	37	1,602	0.5	50
121	GCK-MCI	0.430	2	2	343	38	1,602	1.6	36
122	GLD-MCI	0.170	2	7	382	39	1,602	0.5	28

TABLE 10 (cont'd)

	City Pairs i to j	No. of Passengers T_{ij} in thousands	Attractiveness	Road Conditions	Distance Miles	Population i in thousands	Population j in thousands	# of flights	# of seats
123	GBD-MCI	0.290	2	4	237	54	1,602	2.1	68
124	HYS-MCI	0.880	2	6	253	79	1,602	1.2	39
125	MHK-MCI	4.425	2	7	112	144	1,602	6	256
126	SLN-MCI	1.915	10	9	166	136	1,602	1.7	84
127	ICT-MCI	20.290	15	10	184	539	1,602	12	953
128	MLI-MCI	5.530	6	9	269	220	1,602	1.5	99
129	PIA-MCI	3.570	10	8	281	426	1,602	1	115
130	PDX-MCI	7.165	15	9	1,492	1,123	1,602	1.5	121
131	CID-MSP	9.790	8	6	221	296	2,284	2	197
132	DSM-MSP	22.870	10	10	232	551	2,284	4.7	440
133	SUX-MSP	6.125	6	8	233	223	2,284	1.8	128
134	ALO-MSP	4.405	3	3	166	272	2,284	2	96
135	BJI-MSP	3.745	3	1	199	52	2,284	2	112
136	DLH-MSP	17.080	10	5	144	199	2,284	6	454
137	FRM-MSP	0.950	3	8	104	39	2,284	2	112
138	HIB-MSP	4.755	3	4	174	106	2,284	3	198
139	INL-MSP	2.895	10	1	254	21	2,284	1.5	70
140	STL-MSP	40.165	18	10	448	2,462	2,284	3.8	328
141	OMA-MSP	37.325	14	10	282	765	2,284	4.7	444
142	ICT-MSP	4.000	15	10	545	539	2,284	0.75	46
143	MLI-MSP	9.990	6	9	274	220	2,284	1.2	98
144	PIA-MSP	4.070	10	8	342	426	2,284	2.9	160
145	PDX-MSP	13.750	15	9	1,426	1,123	2,284	3.5	342
146	LBF-LNK	0.490	5	8	207	81	306	1	56
147	BRL-STL	1.715	3	4	146	76	2,462	1.5	72
148	CID-STL	3.975	8	6	228	296	2,462	1.3	110
149	DSM-STL	16.910	10	10	260	551	2,462	4.8	373
150	ALO-STL	1.545	3	3	284	272	2,462	0.4	30
151	CGI-STL	2.855	3	8	114	164	2,462	3.5	140
152	TBN-STL	3.015	3	4	119	105	2,462	5.2	242
153	JLN-STL	4.490	3	5	251	154	2,462	2.3	163
154	IRK-STL	0.205	3	2	150	133	2,462	0.5	24
155	SGF-STL	9.565	12	5	195	356	2,462	4.5	367

TABLE 10 (cont'd)

	City Pairs i to j	No. of Passengers T_{ij} in thousands	Attractiveness		Distance Miles	Population i in thousands	Population j in thousands	# of flights	# of seats
			Road	Conditions					
156	CMI-STL	3.320	10	10	143	182	2,462	3	278
157	MTO-STL	0.280	3	8	123	104	2,462	1	48
158	MLI-STL	8.570	6	9	187	220	2,462	2.8	232
159	MVN-STL	0.625	3	7	87	147	2,462	2	96
160	PIA-STL	7.555	10	8	137	426	2,462	5	370
161	UIN-STL	2.030	3	3	94	96	2,462	3	144
162	RFD-STL	0.915	3	9	247	457	2,462	0.3	12
163	SPI-STL	3.600	10	8	84	246	2,462	9.5	553
164	LNK-STL	2.920	10	8	370	306	2,462	1.3	93
165	OMA-STL	15.850	14	10	342	765	2,462	2.6	174
166	ICT-STL	9.215	15	10	392	539	2,462	2.2	154
167	PDX-STL	5.580	15	9	1,708	1,123	2,462	4.9	412
168	RST-STL	1.435	5	4	373	243	2,462	0.66	41
169	TOP-ICT	0.225	8	10	138	289	539	2	86
170	OMA-ICT	2.198	14	10	265	765	539	1.5	61
171	CID-OMA	2.570	8	6	221	296	765	1.2	105
172	DSM-OMA	6.435	10	10	117	551	765	3	329
173	DBQ-OMA	0.730	8	2	278	145	765	0.8	36
174	FOD-OMA	0.630	3	5	123	174	765	1	48
175	MCW-OMA	0.775	3	5	184	165	765	0.5	24
176	OLU-OMA	0.210	3	3	76	74	765	2	112
177	GRI-OMA	1.155	3	5	128	107	765	1.5	84
178	HSI-OMA	0.405	3	4	141	51	765	1.5	84
179	EAR-OMA	0.455	3	3	167	25	765	1	57
180	MCK-OMA	0.395	2	3	258	37	765	0.66	28
181	OFK-OMA	0.940	2	3	93	121	765	2	112
182	LBF-OMA	1.530	5	8	250	81	765	1	42
183	LNK-OMA	.640	10	8	55	306	765	7	482
184	FRM-OMA	.045	3	8	179	39	765	0.3	14
185	MLI-OMA	2.985	6	9	280	220	765	1	98
186	DSM-ALO	1.055	10	10	96	551	272	2	96
187	DBQ-ALO	0.260	8	2	87	145	272	4	259

TABLE 10 (cont'd)

	City Pairs i to j	No. of Passengers T_{ij} in thousands	Attractiveness	Road Conditions	Distance Miles	Population i in thousands	Population j in thousands	# of flights	# of seats
188	FOD-ALO	.040	3	5	91	174	272	0.5	24
189	MCW-ALO	0.075	3	5	63	165	272	2	163
190	MLI-ALO	0.610	6	9	124	220	272	1.5	139
191	RFD-ALO	0.135	3	9	171	457	272	0.5	24
192	OMA-ALO	1.480	14	10	200	765	272	1.3	60
193	RST-ALO	0.360	5	4	93	243	272	3	211
194	STL-ALO	1.545	18	10	284	2,462	272	0.3	12
195	CHO-WAS	4.56	10	5	84	147	3,080	6.0	318
196	LYH-WAS	4.43	4	4	152	166	3,080	5.5	232
197	PHF-WAS	13.31	8	9	129	347	3,080	6.5	661
198	ORF-WAS	53.42	12	8	149	786	3,080	11.8	941
199	ROA-WAS	16.71	5	6	184	374	3,080	7.0	539
200	DTW-WAS	97.5	20	10	391	4,788	3,080	14.7	1,400
201	GRR-WAS	5.24	15	9	513	729	3,080	1.6	95
202	FNT-WAS	2.58	15	10	441	533	3,080	0.5	50
203	LAN-WAS	5.92	15	9	468	500	3,080	1.9	119
204	MBS-WAS	3.62	10	8	478	608	3,080	1.8	90
205	PDX-WAS	10.38	15	9	2,339	1,123	3,080	4.0	340
206	LYH-ORF	0.61	4	4	168	166	786	0.3	12
207	ROA-ORF	4.71	5	6	210	374	786	2	143
208	CHO-ROA	0.125	10	5	101	147	374	2.8	247
209	PHF-ROA	0.915	8	9	192	347	374	0.66	27
210	RIC-ROA	8.74	18	9	147	893	374	5	417
211	ORF-DTW	9.43	12	8	527	786	4,788	2.1	163
212	ROA-DTW	1.91	5	6	384	374	4,788	0.3	24
213	GRR-DTW	9.26	15	9	126	729	4,788	6	417
214	LAN-DTW	4.37	15	9	79	500	4,788	9.5	538
215	MKG-DTW	2.14	5	9	166	231	4,788	3	168
216	MBS-DTW	5.29	10	8	96	608	4,788	5	340
217	PDX-DTW	6.36	15	9	1,959	1,123	4,788	5.2	491
218	EUG-PDX	4.80	10	7	106	367	1,123	6.5	478
219	WAS-NYC	833.47	20	10	215	3,080	17,865	73.2	7,652

TABLE 10 (cont'd)

	City Pairs i to j	No. of Passengers T_{ij} in thousands	Attractiveness	Road Conditions	Distance Miles	Population i in thousands	Population j in thousands	# of flights	# of seats
220	CHO-NYC	10.40	10	5	299	147	17,865	3.5	258
221	LYH-NYC	7.01	4	4	366	166	17,865	4.3	305
222	PHF-NYC	24.01	8	9	283	347	17,865	7.7	658
223	ORF-NYC	76.40	12	8	291	786	17,865	7.5	932
224	RIC-NYC	58.85	18	9	286	893	17,865	9.9	871
225	ROA-NYC	19.43	5	6	399	374	17,865	6.2	469
226	DTW-NYC	399.72	20	10	489	4,788	17,865	38	4,000
227	GRR-NYC	20.44	15	9	614	729	17,865	3.8	241
228	MBS-NYC	13.83	10	8	553	608	17,865	4.5	277
229	PDX-NYC	25.62	15	9	2,241	1,123	17,865	9.5	1,106

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TABLE 11

City Character

Legend

MC - marketing centres
INT - institutional
BAL - balanced
IND - industrial

		manufacturing % employed	wholesale and retail trade	educational services	government	prof., tech., mgrs., admin.	city type
<u>IOWA</u>							
1.	Des Moines (DSM)	19.0	23.3	7.4	14.2	25.6	BAL
2.	Fort Lodge (FOD)	21.3	29.4	7.2	11.7	24.2	BAL
3.	Burlington (BRN)	36.7	23.2	6.0	10.9	22.7	IND
4.	Keokuk (EOK)	10.4	21.4	7.3	12.2	15.9	MC
5.	Marshalltown (MIW)	36.3	21.3	7.2	11.9	23.7	IND
6.	Cedar Rapids (CID)	34.7	20.2	7.7	9.5	24.3	IND
7.	Mason City (MCW)	18.6	28.5	8.3	11.2	24.2	MC
8.	Ottumwa (OTM)	29.5	23.0	6.9	11.9	22.8	BAL
9.	Spencer (SPW)	11.9	27.4	6.5	11.7	20.4	MC
10.	Waterloo (ALO)	30.1	22.3	10.8	13.8	21.9	IND
11.	Clinton (CWI)	36.0	19.4	6.6	9.4	21.7	IND
12.	Dubuque (DBO)	32.5	19.3	9.7	7.4	21.7	IND
13.	Davenport (DVN)	29.2	24.0	7.6	15.2	23.6	BAL
14.	Fort Madison (QTM)	34.5	18.5	6.3	13.1	21.6	IND
15.	Sioux City (SUX)	17.4	26.5	8.1	11.7	23.6	MC
<u>MINNESOTA</u>							
16.	Beaumont (BJI)	7.5	23.9	21.8	37.2	26.3	INT
17.	Brainerd (BRD)	14.3	24.2	8.7	23.4	26.6	MC
18.	Hibbing (HIB)	14.0	21.4	9.2	17.8	22.8	MC
19.	Eveleth (EVM)	14.0	21.4	9.2	17.8	22.8	MC
20.	Fairmont (FRM)	17.7	24.2	7.2	10.0	18.0	MC
21.	Grand Rapids (GPZ)	14.6	19.3	11.9	24.1	21.0	INT
22.	International Falls (INL)	40.0	16.0	9.8	18.4	19.7	IND
23.	Mankato (MKT)	15.6	25.9	15.2	19.9	23.0	MC
24.	New Ulm (ULM)	22.9	21.7	7.2	9.4	18.0	BAL
25.	Thief River Falls (TVF)	16.9	27.8	8.5	15.1	22.2	MC
26.	Winona (ONA)	24.3	19.2	15.3	14.2	21.9	IND
27.	Worthington (WTC)	14.2	23.8	9.1	13.5	20.5	MC
28.	Duluth (DLH)	14.0	21.4	9.2	17.8	22.8	MC

TABLE 11 (cont'd)

Legend

MC - marketing centres
 INT - institutional
 BAL - balanced
 IND - industrial

		Manufacturing % employed	Wholesale and retail trade	Educational services	Government	Prof., tech., mgrs., admin.	City type
29.	Rochester (RST)	16.4	19.8	6.0	11.4	35.2	BAL
30.	Minneapolis- St. Paul (MSP)	24.7	23.0	8.3	14.4	27.3	BAL
<u>MISSOURI</u>							
31.	Cape Girardeau (CGI)	19.9	24.2	11.5	15.2	22.5	BAL
32.	Jefferson City (JEF)	10.8	17.7	8.7	24.9	26.9	INT
33.	Joplin (JLN)	28.1	25.3	6.5	10.5	21.3	BAL
34.	Kirkville (IRK)	14.0	20.8	19.0	23.0	23.1	BAL
35.	Rolla (RLA)	9.5	21.2	19.0	35.6	29.0	INT
36.	Springfield (SGF)	20.3	24.6	8.3	12.8	23.0	BAL
37.	Columbia (COU)	6.0	17.0	31.4	41.6	32.6	INT
38.	St. Louis (STL)	27.6	23.9	8.2	12.0	30.7	BAL
39.	Sedalia (DMO)	21.6	23.8	5.4	11.6	18.6	BAL
40.	Malden (MAW)	23.6	20.9	8.5	15.5	19.0	BAL
41.	Kansas City (MCI)	23.7	23.0	5.7	15.3	21.5	BAL
42.	Poplar Bluff (POF)	15.2	25.2	7.4	15.5	20.9	MC
43.	Ft. Leonard Wood (TBN)	11.1	28.7	10.4	34.8	20.3	INT
<u>NEBRASKA</u>							
44.	Alliance (AIA)	3.0	27.2	8.0	14.5	23.8	MC
45.	Chadron (CDR)	2.2	22.8	19.4	29.6	25.0	INT
46.	Columbus (OLU)	29.8	18.9	5.9	9.8	18.9	IND
47.	Grand Island (GRI)	20.1	25.9	5.7	13.6	21.9	BAL
48.	Hastings (HSI)	16.6	24.3	8.3	18.1	23.5	MC
49.	Kearney (EAR)	7.3	19.4	8.5	14.7	17.4	MC
50.	McCook (MCK)	10.0	26.2	8.3	15.3	23.6	MC
51.	Norfolk (OFK)	15.3	26.7	6.6	14.8	21.3	MC
52.	North Platte (LBF)	5.4	24.1	6.8	13.8	20.2	MC
53.	Scottsbluff (BFF)	13.6	27.6	9.5	13.3	23.1	MC

TABLE 11 (cont'd)

LEGEND

MC - marketing centres
 INT - institutional
 BAL - balanced
 IND - industrial

	Manufacturing % employed	Wholesale and retail trade	Educational services	Government	Prof., tech., mgrs., admin.	City type
54. Sidney (SNY)	5.8	26.1	7.6	15.4	19.8	MC
55. Lincoln (LNK)	12.3	21.4	14.5	25.2	27.3	INT
56. Omaha (OMA)	17.2	24.0	7.1	13.1	25.5	MC
<u>ILLINOIS</u>						
57. Carbondale (MDH)	12.0	17.7	30.4	38.9	29.9	INT
58. Danville(DNV)	37.2	19.2	6.7	12.3	18.0	IND
59. Galesburg (GBG)	27.3	17.9	8.1	13.6	18.8	IND
60. Jacksonville (IJX)	19.1	18.2	12.0	17.4	20.7	BAL
61. Macomb (MQB)	13.1	24.5	21.2	28.2	22.8	INT
62. Mattoon (MTO)	22.0	19.5	18.1	24.1	20.7	BAL
63. Mount Vernon (MNV)	19.0	23.2	6.7	13.2	18.2	BAL
64. Quincy (UIN)	28.2	22.1	6.7	8.8	19.3	BAL
65. Sterling/Rock Falls (SQI)	39.0	17.3	6.4	11.1	15.5	IND
66. Bloomington (BMI)	16.1	20.0	16.6	19.6	24.7	BAL
67. Chicago (CHI)	31.7	20.8	6.2	11.7	23.0	IND
68. Champaign (CMI)	8.8	19.0	30.7	38.9	34.3	INT
69. Decatur (DEC)	33.6	18.8	6.7	10.2	20.7	IND
70. Centralia (ENL)	22.3	18.8	5.9	13.2	18.7	BAL
71. Moline (MLI)	28.9	20.0	6.5	11.4	16.3	IND
72. Peoria (PIA)	31.7	21.2	7.0	10.9	22.2	IND
73. Rockford (RFD)	45.2	18.7	5.4	8.4	20.0	IND
74. Springfield(SPI)	14.5	19.3	6.7	25.3	24.1	INT
<u>KANSAS</u>						
75. Dodge City (DDC)	11.1	24.7	8.9	14.7	23.7	MC
76. Garden City(GCK)	9.4	27.1	11.0	16.8	21.8	MC
77. Goodland (GLD)	4.5	25.4	4.6	13.6	16.3	MC
78. Great Bend (GBD)	9.7	24.7	4.9	10.4	23.1	MC
79. Hays (HYS)	7.6	23.2	18.8	23.2	25.8	INT

TABLE 11 (cont'd)

LEGEND

MC - marketing centres
 INT - institutional
 BAL - balanced
 IND - industrial

		Manufacturing % employed	Wholesale and retail trade	Educational services	Government	Prof., techn., mgrs., admin.	City type
80.	Hutchinson (HUT)	20.8	27.3	7.4	12.8	23.8	BAL
81.	Lawrence (LWC)	17.0	17.6	27.9	35.5	30.8	INT
82.	Liberal (LBL)	12.2	26.9	7.5	12.8	20.3	MC
83.	Manhattan (MHK)	4.4	20.1	31.7	41.4	31.6	INT
84.	Olathe (OJC)	19.2	26.0	7.8	13.6	36.9	MC
85.	Salina (SLN)	12.3	26.8	9.6	14.5	25.6	MC
86.	Wichita (ICT)	27.2	22.1	7.9	13.3	25.7	BAL
87.	Parsons (PPF)	32.1	16.1	7.3	14.9	15.8	IND
88.	Topeka (TOP)	14.3	20.3	7.0	22.7	24.7	INT

VIRGINIA

89.	Lynchburg (LYB)						
90.	Newport News (PHF)	24.9	18.2	8.4	27.5	26.2	BAL
91.	Norfolk (ORF)	14.6	22.9	7.4	29.6	22.6	INT
92.	Richmond (RIC)	21.0	20.8	7.8	20.1	24.6	BAL
93.	Roanoke (ROA)	21.0	22.9	6.5	13.0	22.4	BAL
94.	Charlottesville (CHO)	12.0	18.4	17.7	35.2	32.7	INT
95.	Danville (DAN)	41.1	17.9	6.8	11.7	18.2	IND
96.	Hot Springs (HSP)	15.7	10.6	3.5	12.4	17.1	BAL
97.	Manassas (MNS)	8.7	18.7	9.5	33.8	28.8	INT
98.	Pulaski (PSK)	49.0	14.0	4.9	11.1	14.3	IND
99.	Staunton (SHD)	38.2	14.5	5.7	14.5	17.5	IND

MICHIGAN

100.	Detroit (DTW)	37.4	19.8	6.6	12.1	21.9	IND
101.	Grand Rapids (GRR)	31.8	24.0	7.2	9.3	21.0	BAL
102.	Flint (FNT)	46.3	18.0	7.6	11.3	17.2	IND
103.	Lansing (LAN)	21.4	19.0	19.3	30.6	26.8	INT
104.	Muskegon (MKG)	44.4	18.0	6.9	11.1	18.7	IND
105.	Saginaw (MBS)	38.8	20.4	6.6	10.2	18.5	IND
106.	Alpena (APN)	29.9	21.6	11.2	19.2	20.5	IND
107.	Kalamazoo (AZO)	33.4	19.7	12.9	17.3	24.4	IND

TABLE 11 (cont'd)

LEGEND

MC - marketing centres
 INT - institutional
 BAL - balanced
 IND - industrial

		Manufacturing % employed	Wholesale and retail trade	Educational services	Government	Prof., tech., mgrs., admin.	City type
108.	Benton Harbor (BEH)	43.2	17.8	7.5	9.0	20.4	IND
109.	Battle Creek (BTL)	36.0	18.0	7.0	14.6	19.2	IND
110.	Hancock (CMX)	8.7	23.2	23.1	26.9	24.9	INT
111.	Escanaba (ESC)	26.6	22.3	7.6	13.7	21.1	BAL
112.	Iron Mountain (IMT)	21.8	24.3	7.2	16.9	22.5	BAL
113.	Iron Wood (IWD)	17.7	22.4	7.1	17.7	18.0	BAL
114.	Jackson (JXN)	35.7	19.4	7.0	12.3	20.9	IND
115.	Manistee (MBL)	39.5	18.2	6.1	14.8	18.3	IND
116.	Minominee (MMN)	37.7	19.8	6.2	12.2	15.4	IND
117.	Marquette(MQT)	6.3	21.3	16.5	27.2	22.1	INT
118.	Pellston (PLN)	15.5	25.7	7.9	14.6	23.8	MC
119.	Sault Ste. Marie (SSM)	5.7	26.9	13.8	34.8	23.6	INT
120.	Traverse City (TVC)	17.7	24.4	7.2	17.0	25.3	BAL
<u>OREGON</u>							
121.	Eugene (EUG)	23.4	21.8	13.4	18.9	24.5	BAL
122.	Portland (PDX)	21.0	23.1	8.1	14.3	25.0	BAL
123.	Washington, D.C.	6.5	16.8	8.5	39.1	35.3	INT
134.	New York, New York	20.7	19.9	7.2	16.6	26.0	BAL

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TABLE 12

VARIABLES AND THEIR DEFINITIONS

<u>No.</u>	<u>Variable</u>	<u>Definition</u>
1	No. of passengers between cities	No. of enplanements from city i to city j
2	Population of the region	The population of the community which is handled by an airport.
3	Travel cost	Coach air fare from the airport of region i to the airport of region j + the cost to reach the airport from the central city in region i + the cost to reach the central city in region j from the airport
4	Travel time	Actual flight time from the airport in region i to the airport in region j + travel time from the central city in region i to the airport + travel time from the airport in region j to the central city + 45 minutes for ticket and luggage check in at region i and luggage check out at region j
5	Reliability of the flights	Reliability of the service of flight in region i
6	No. of flights between two cities	A function of the no. of direct flights without stop, no. of direct flights with stops, and the no of connecting flights between regions i and j
7	No. of available seats in the planes	A function of the no. of available seats in the direct flights and connecting flights between region i and j
8	Attractiveness of the City	Relative attractiveness of the cities were compared and nos. were given to each city out of a maximum of 20
9	Road conditions of the city	Relative road conditions of the cities were compared and nos. were given to each city out of a maximum of 10
10	Economic characteristics of the community	Communities were divided into 4 categories: Industrial, Marketing, Institutional and Balanced Communities, and the percent employment in each category determined

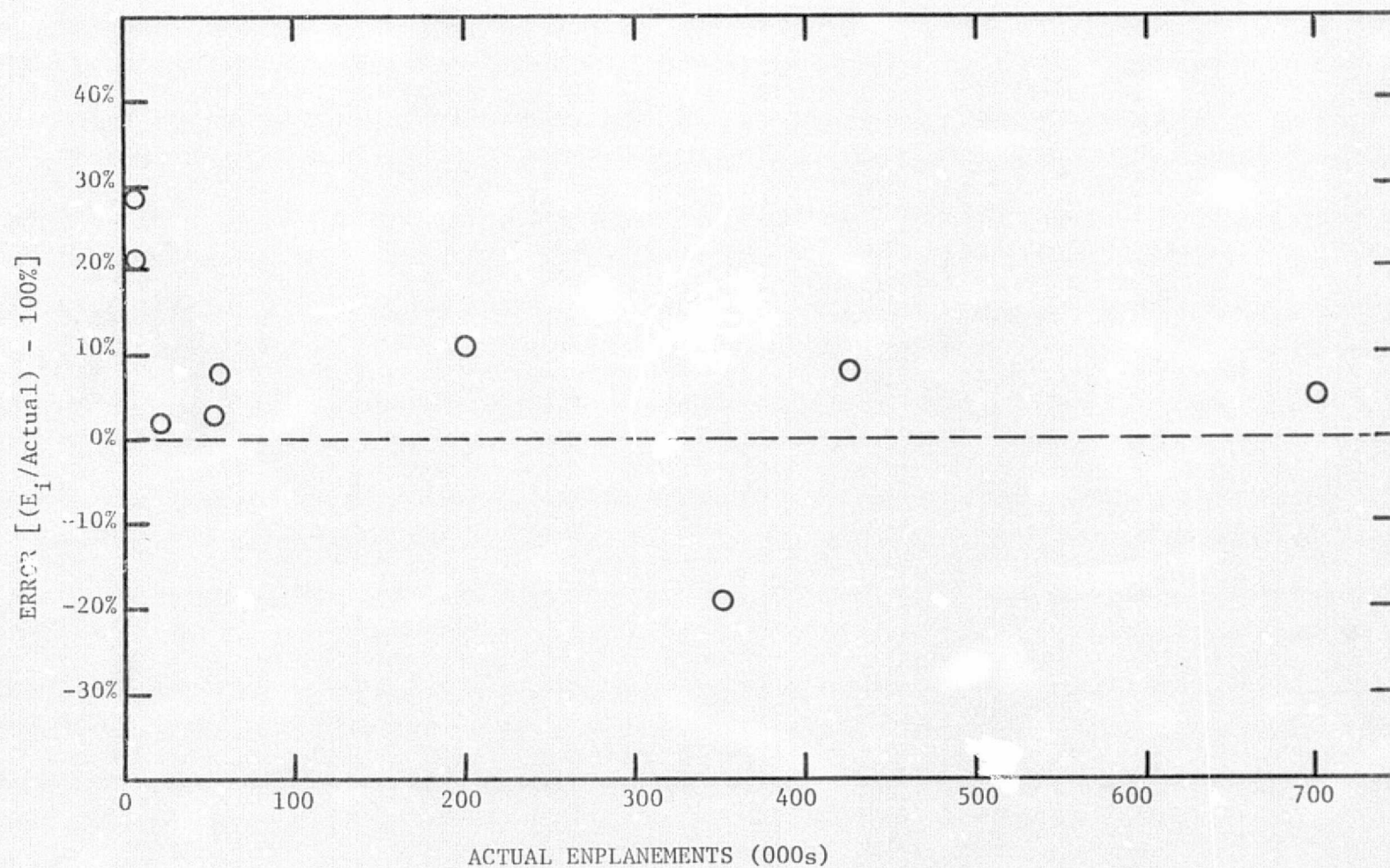


Figure 1(a) Error vs. Actual Enplanements for Virginia Airports, 1974

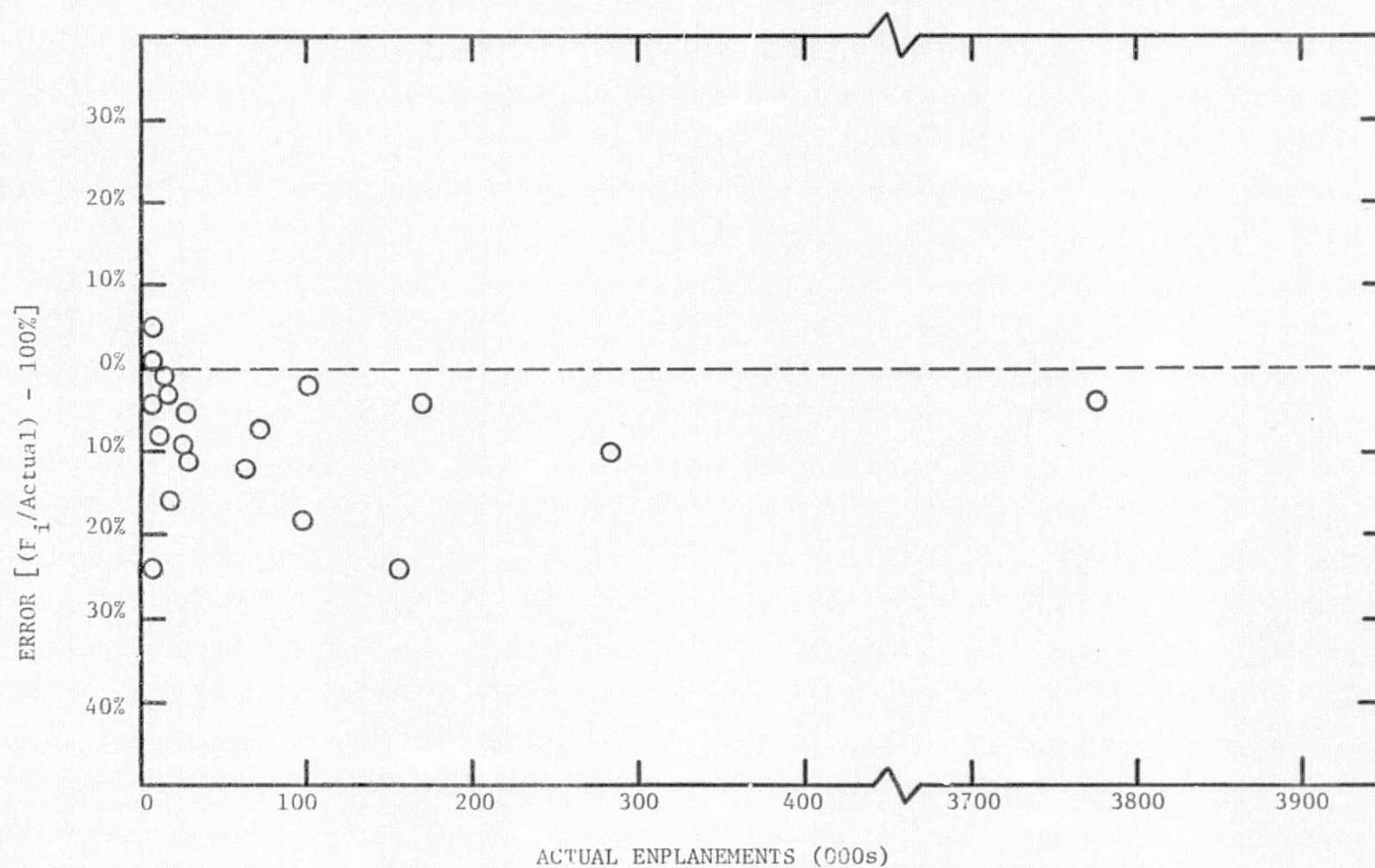


Figure 1(b) Error vs. Actual Enplanements for Michigan Airports, 1974

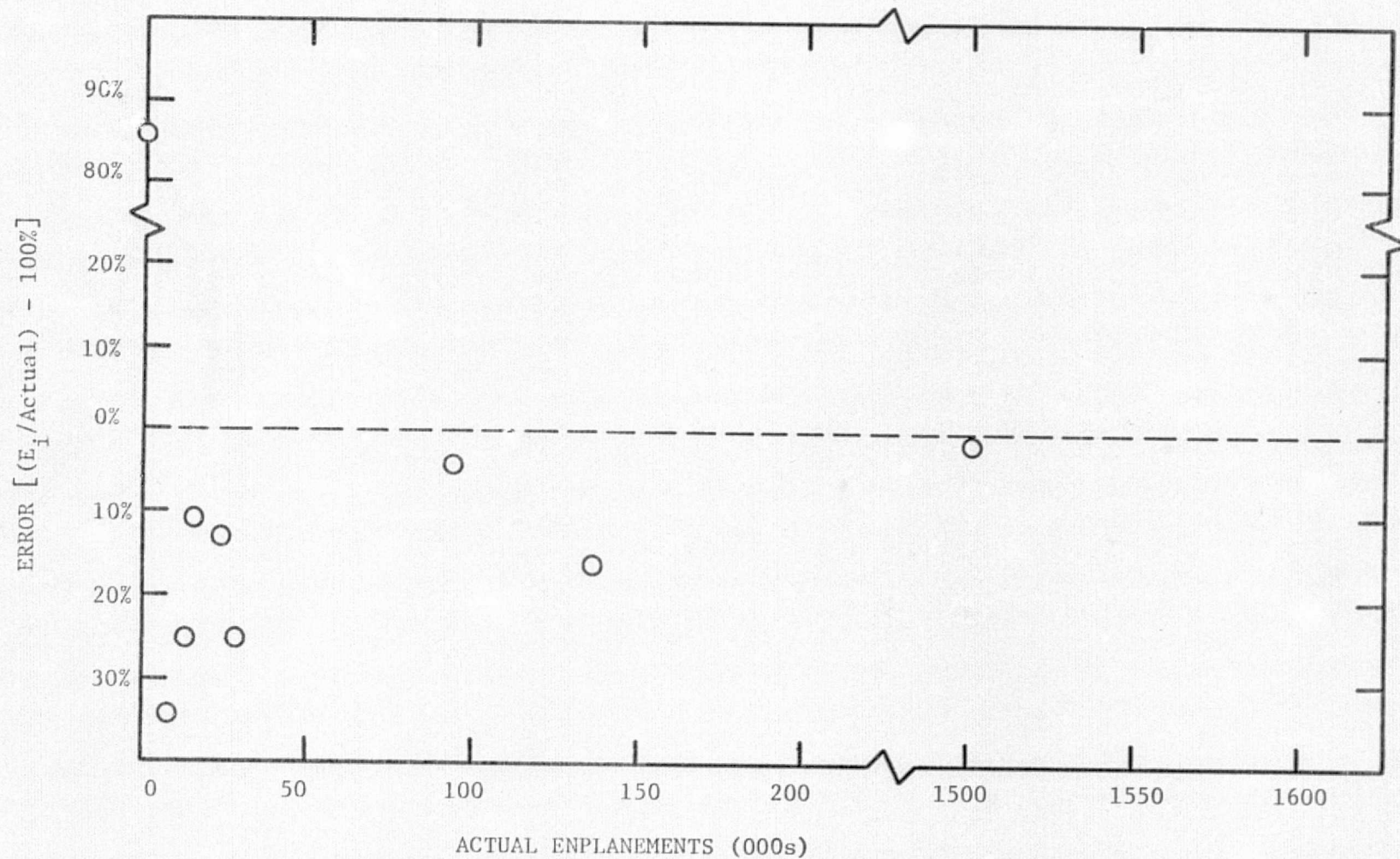


Figure 1(c) Error vs. Actual Enplanements for Oregon Airports, 1974

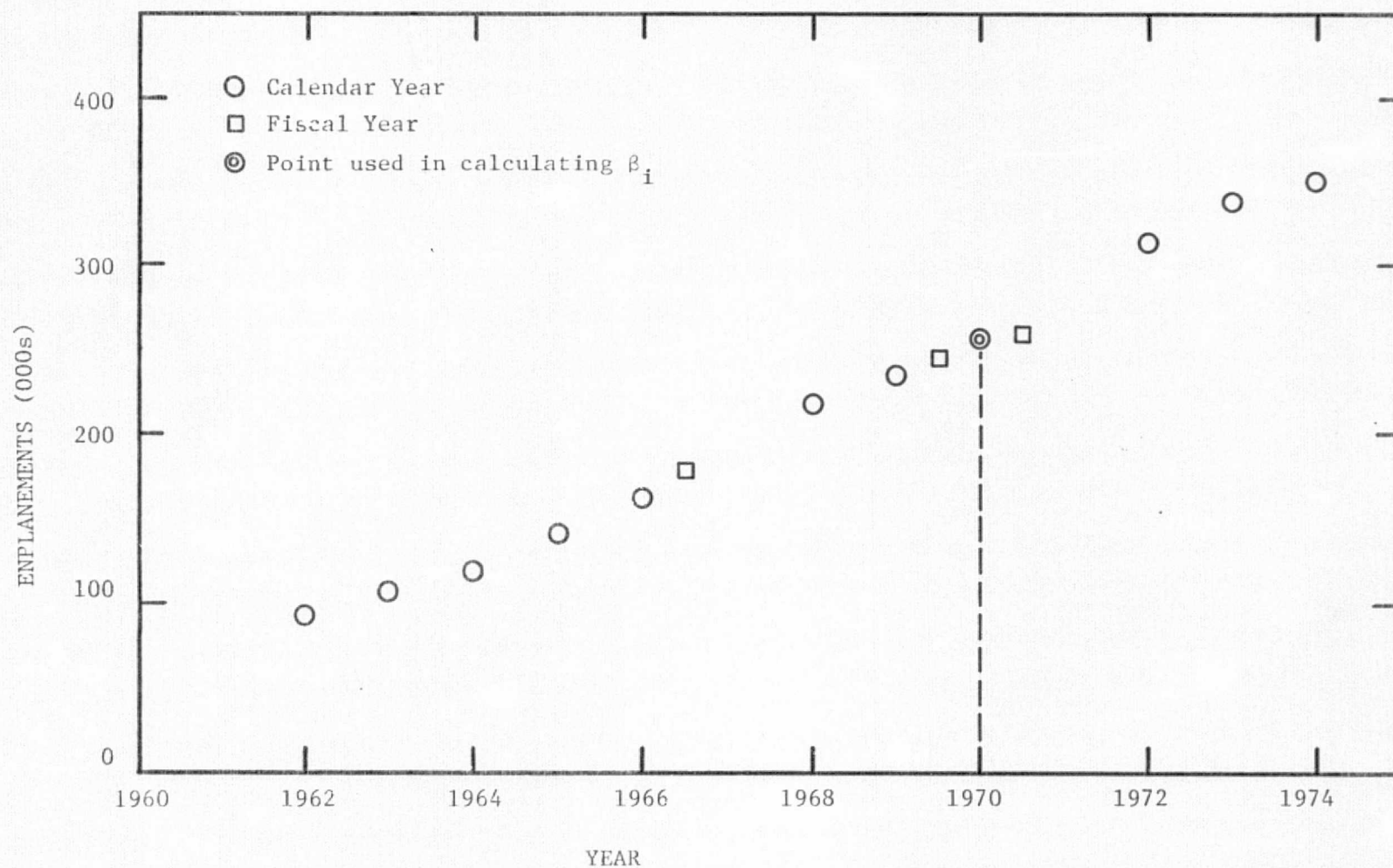


Figure 2(a) Historical Trend in Enplanements for Roanoke, Va., 1962-1974

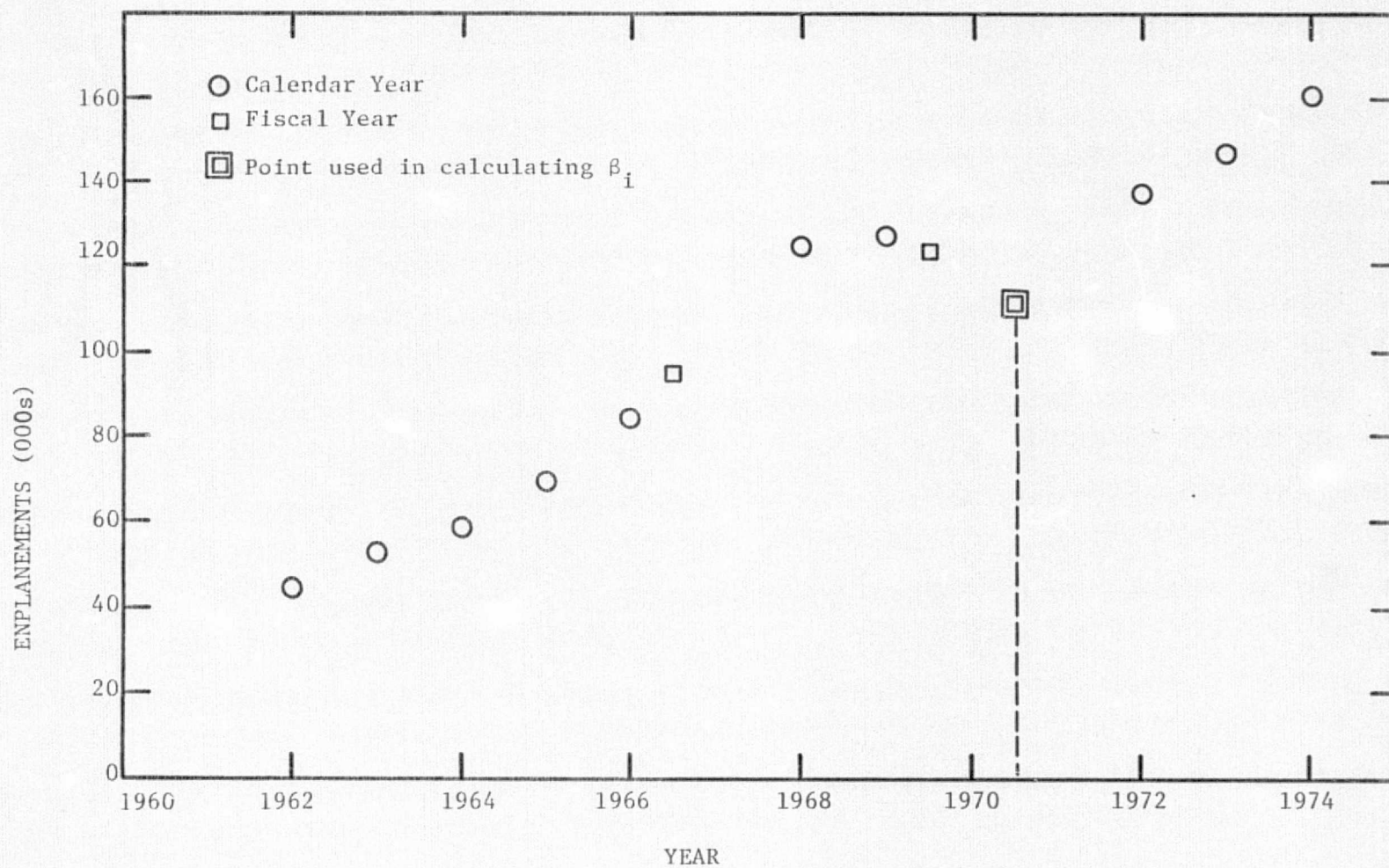


Figure 2(b) Historical Trend in Enplanements for Lansing, Mich., 1962-1974.

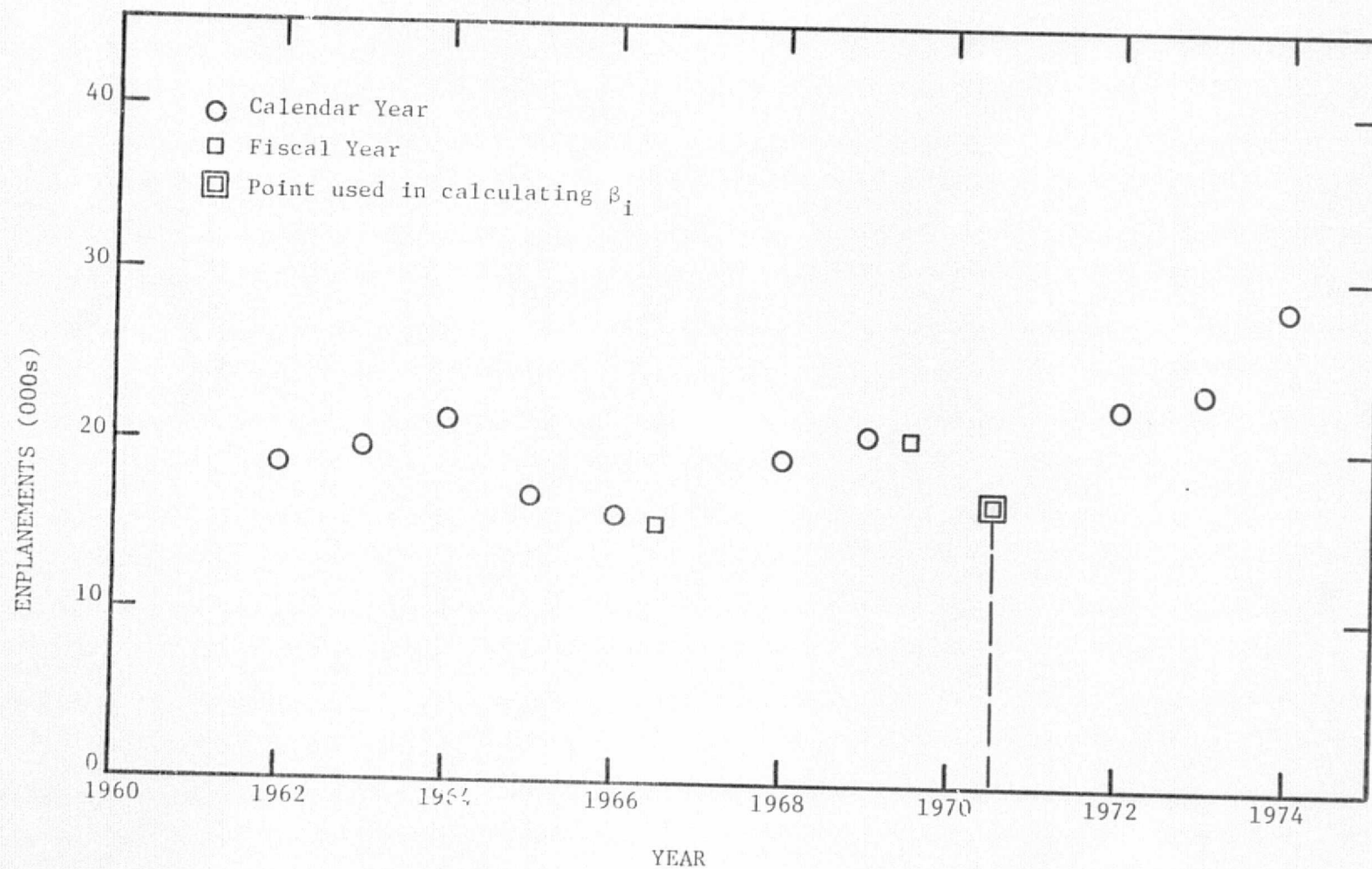


Figure 2(c) Historical Trend in Enplanements for Pendleton, Ore., 1962-1974

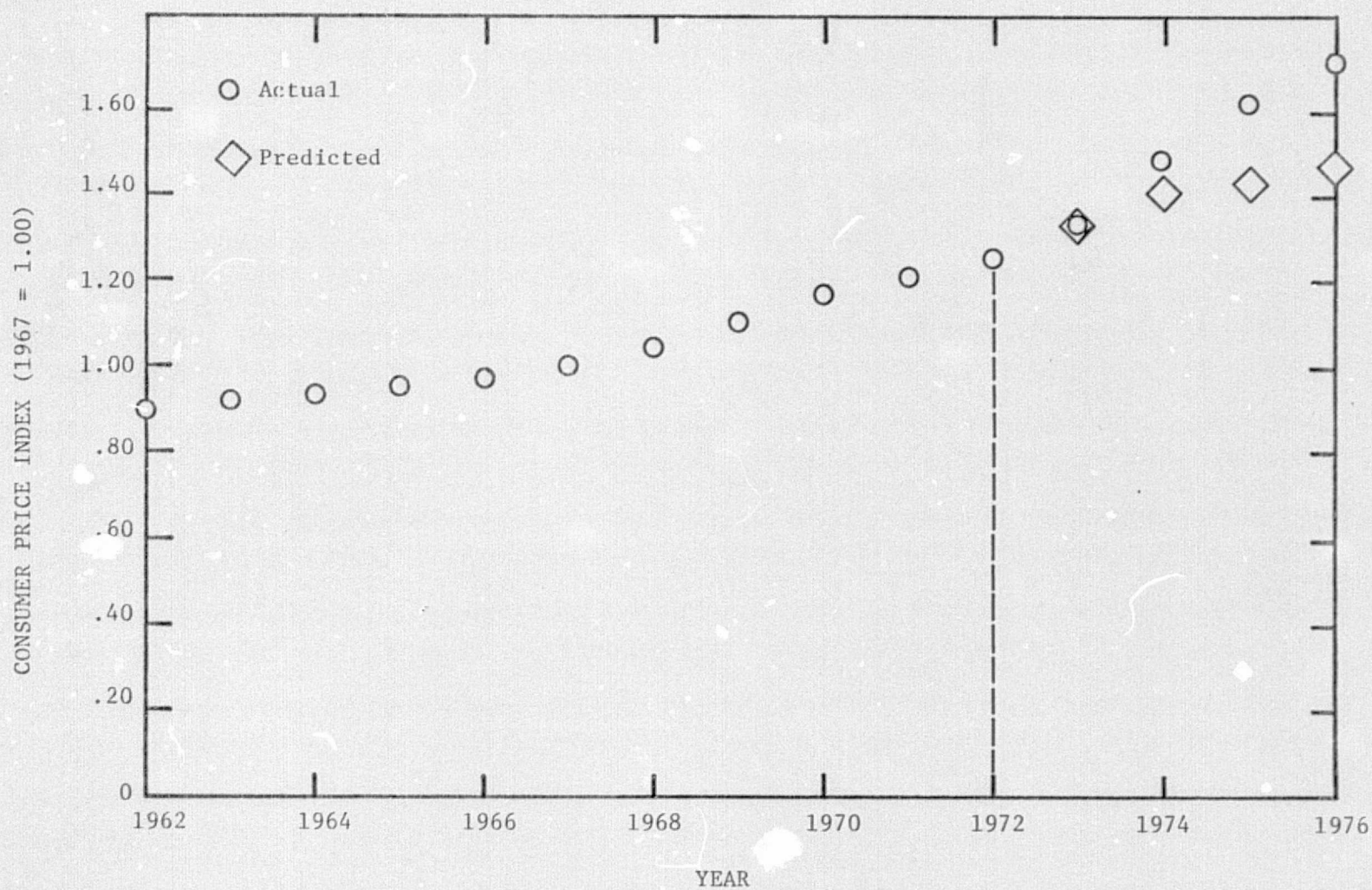


Figure 3(a) Consumer Price Index vx. Year, 1962-1976

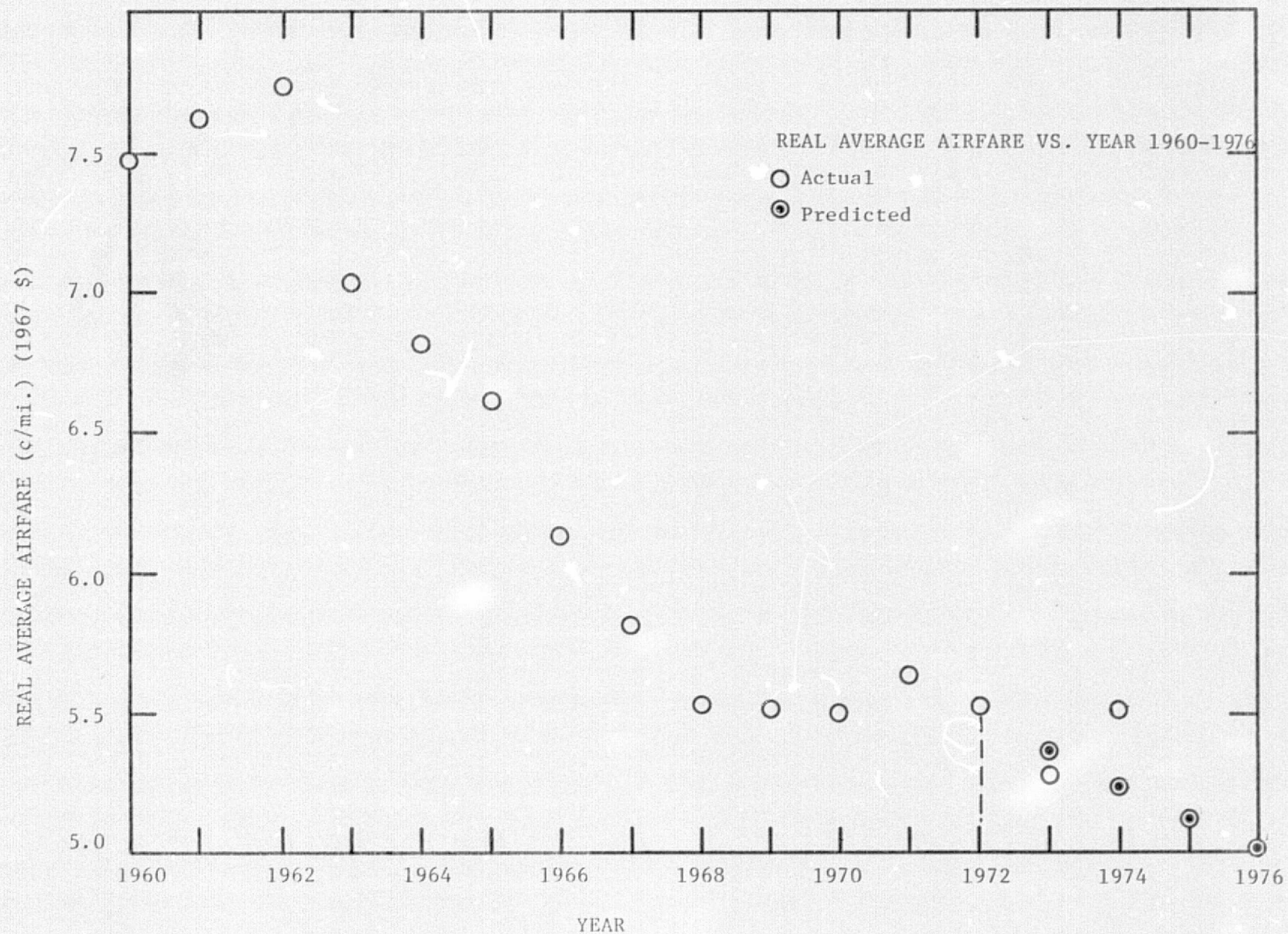


Figure 3(b) Real Average Airfare vs. Year 1960-1976

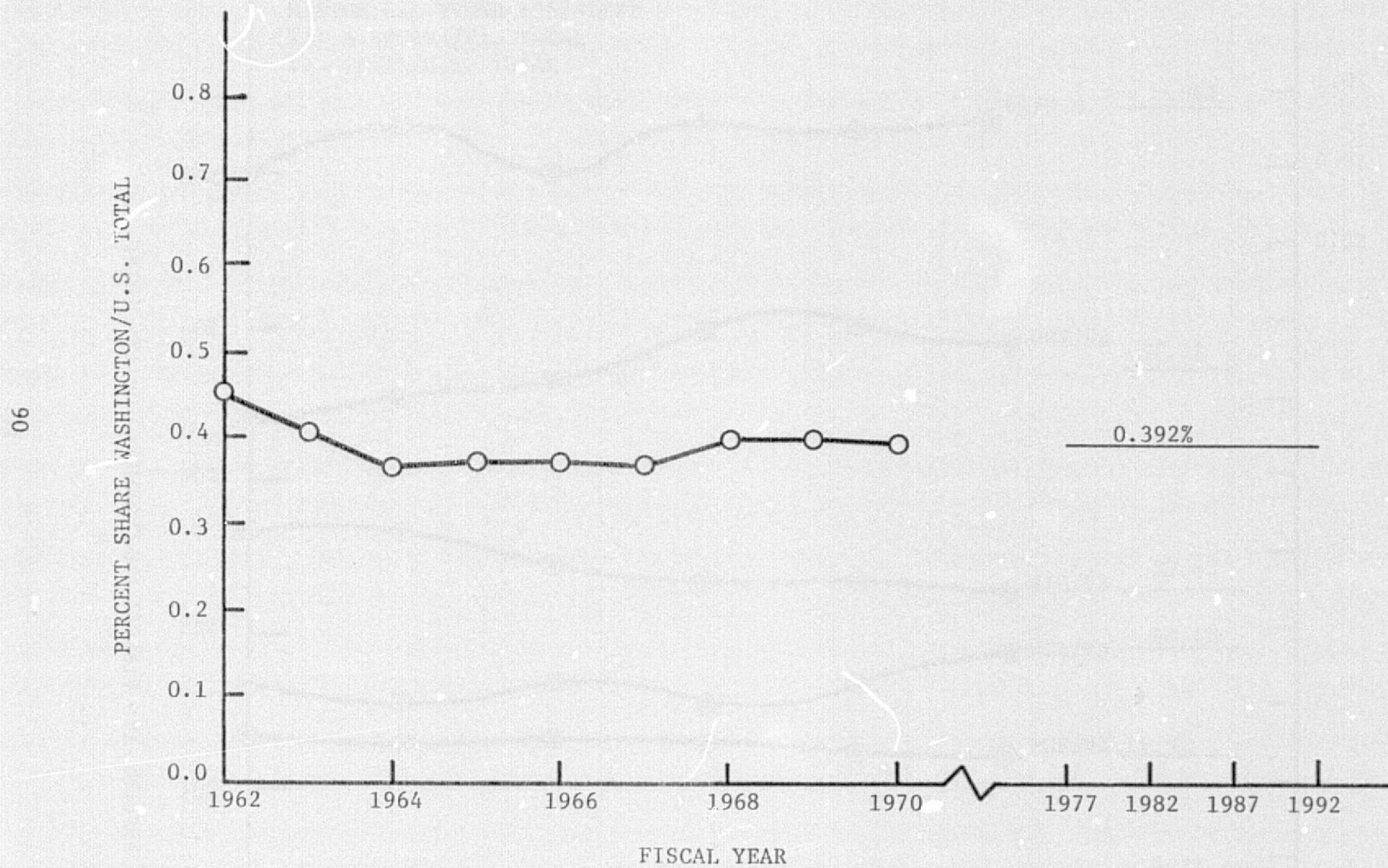


Figure 4(a) Historical Trend of Market Share of Washington/U.S. Total

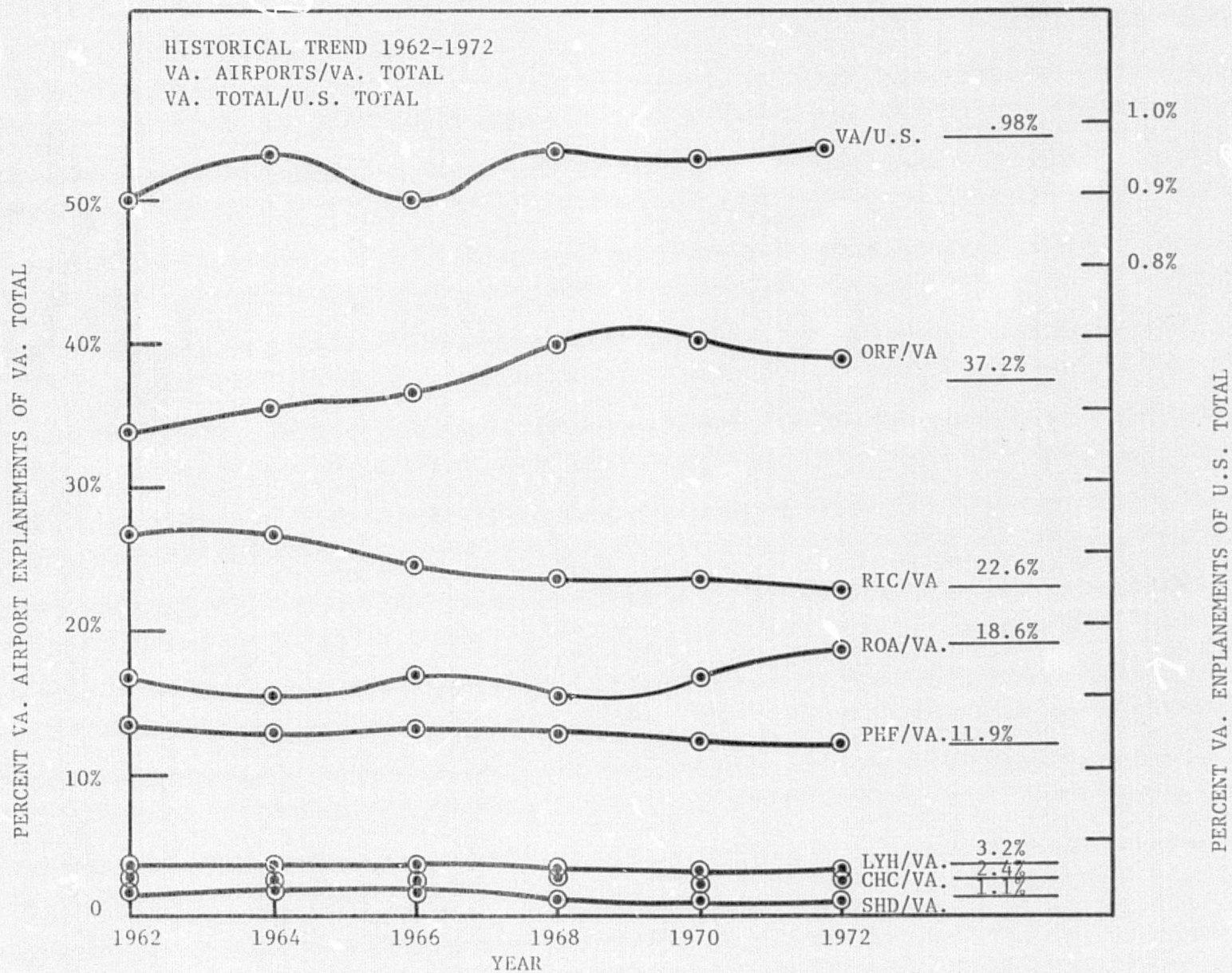


Figure 4(b) Share of Market vs. Year, Virginia 1962-1972

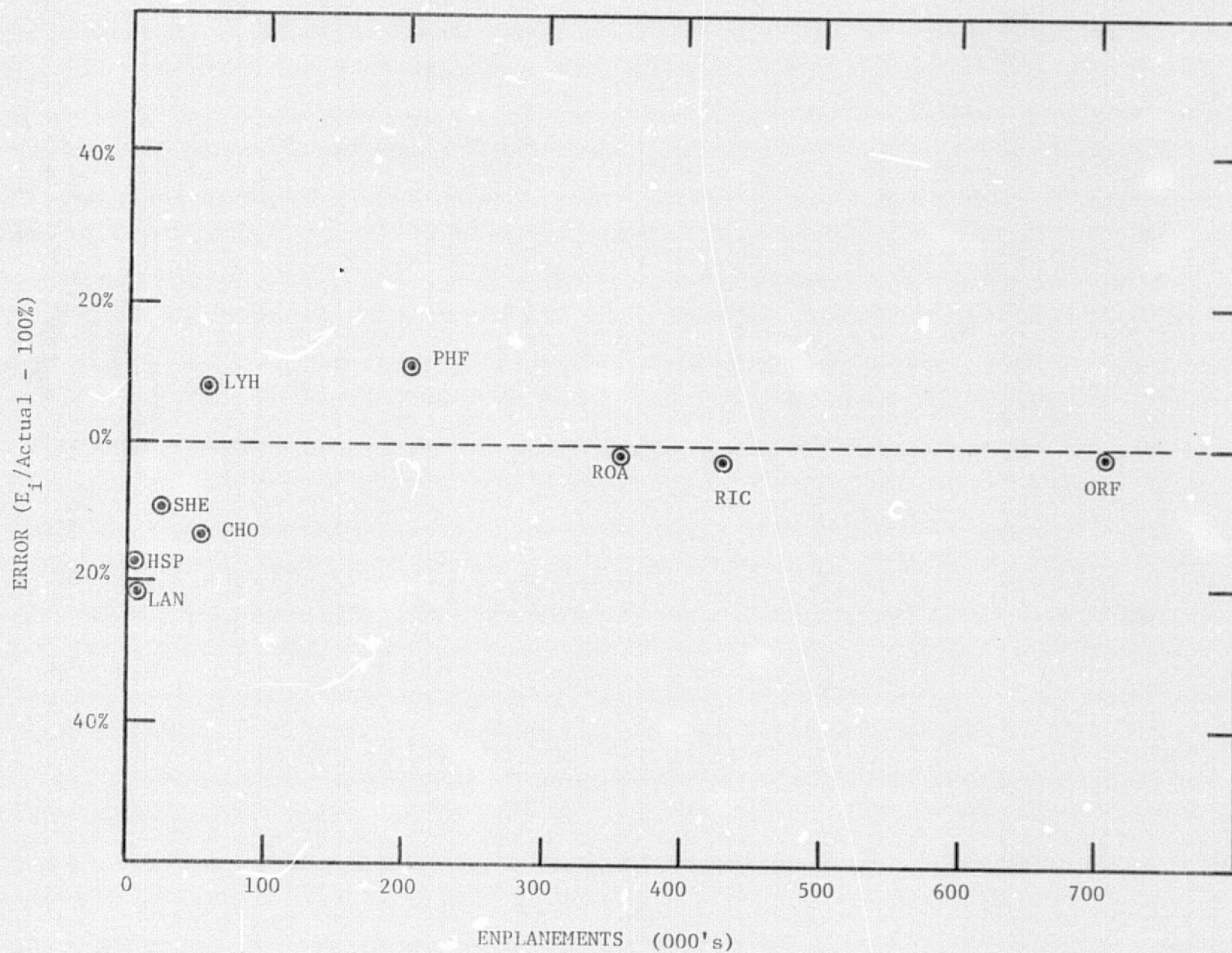


Figure 5(a) Error vs. Enplanements for Virginia Airports, 1974

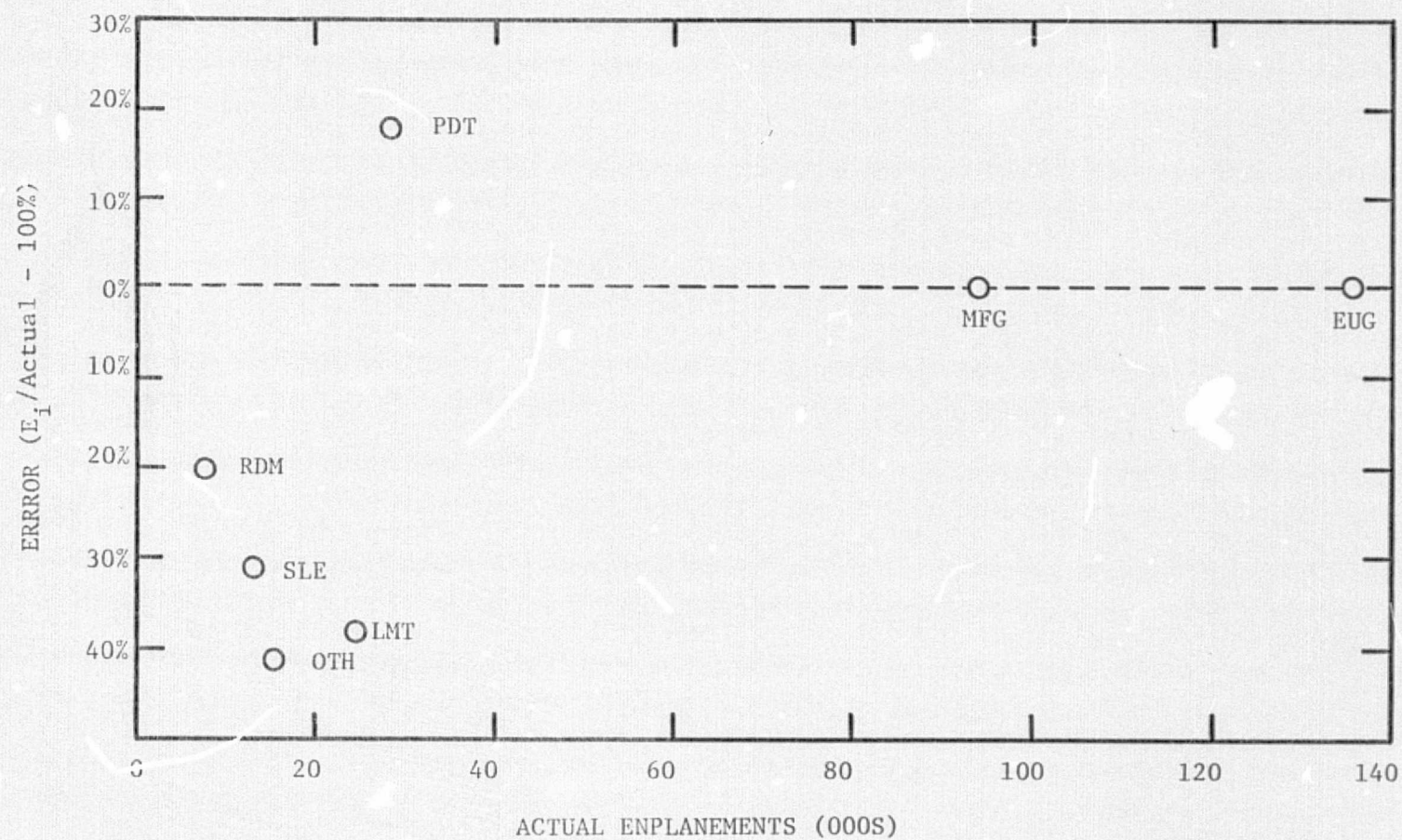


Figure 5(b) Error vs. Actual Enplanements for Oregon Airports, 1974

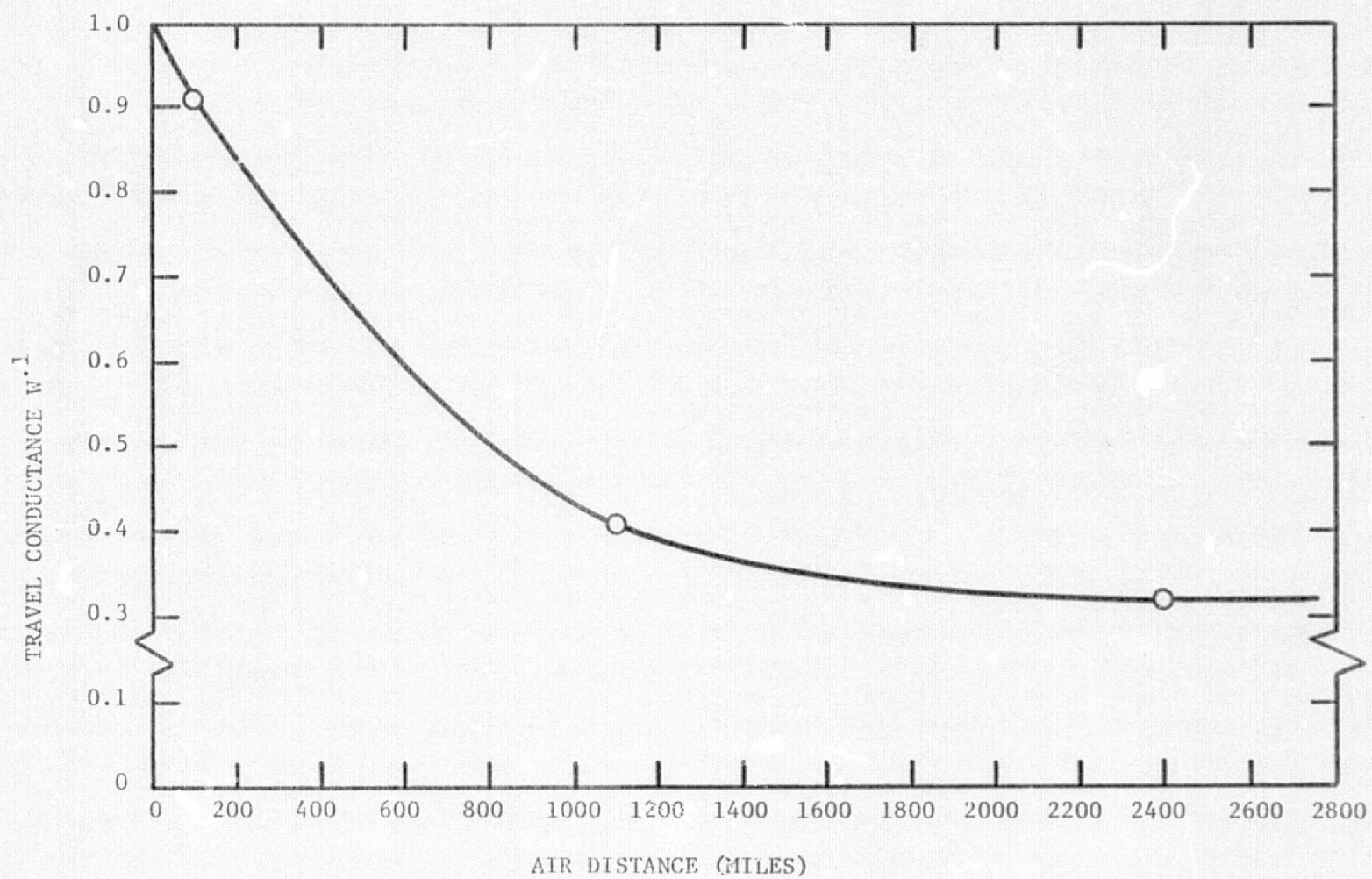


Figure 6(a) Travel Conductance, $W \cdot l$ vs Air Distance

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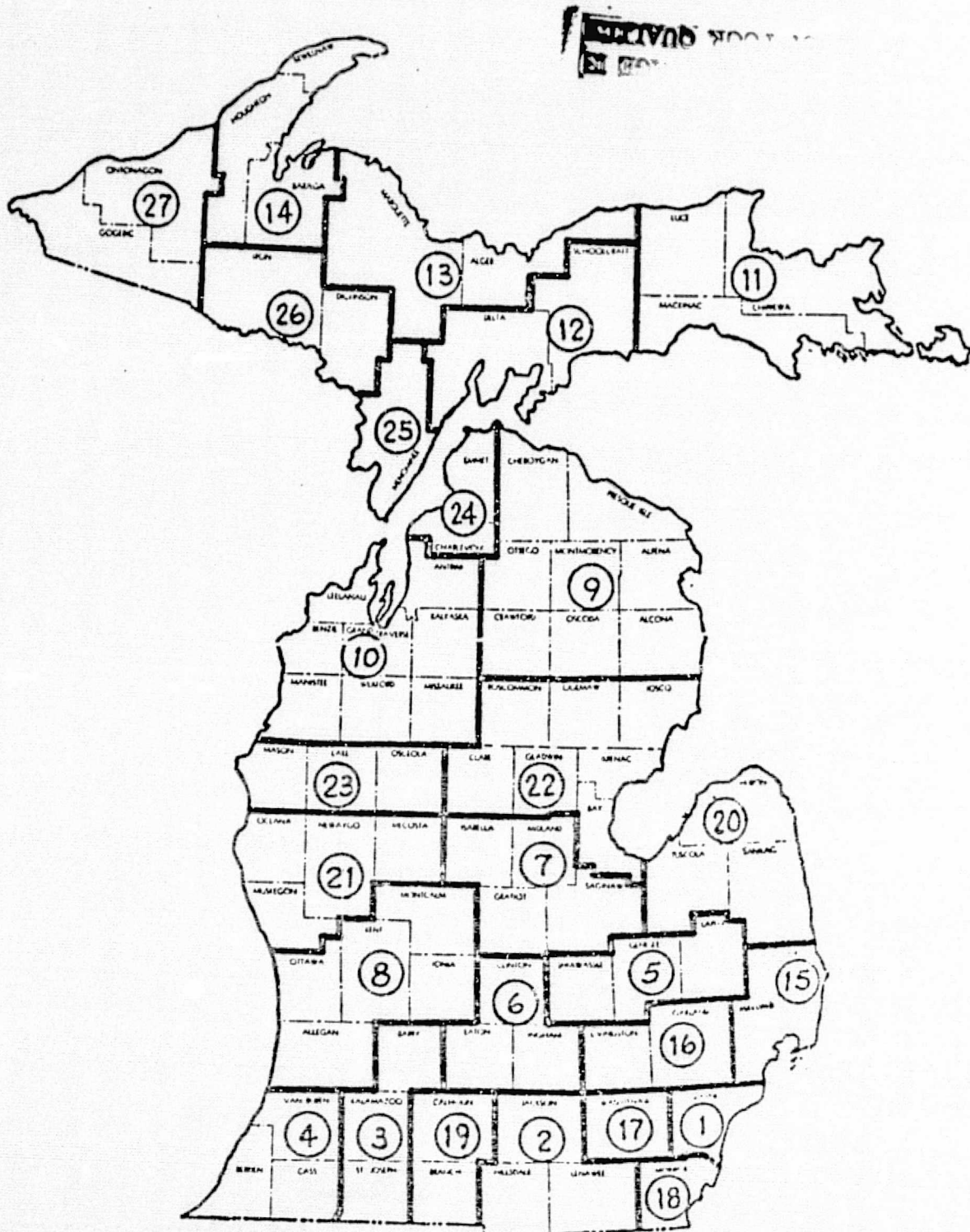
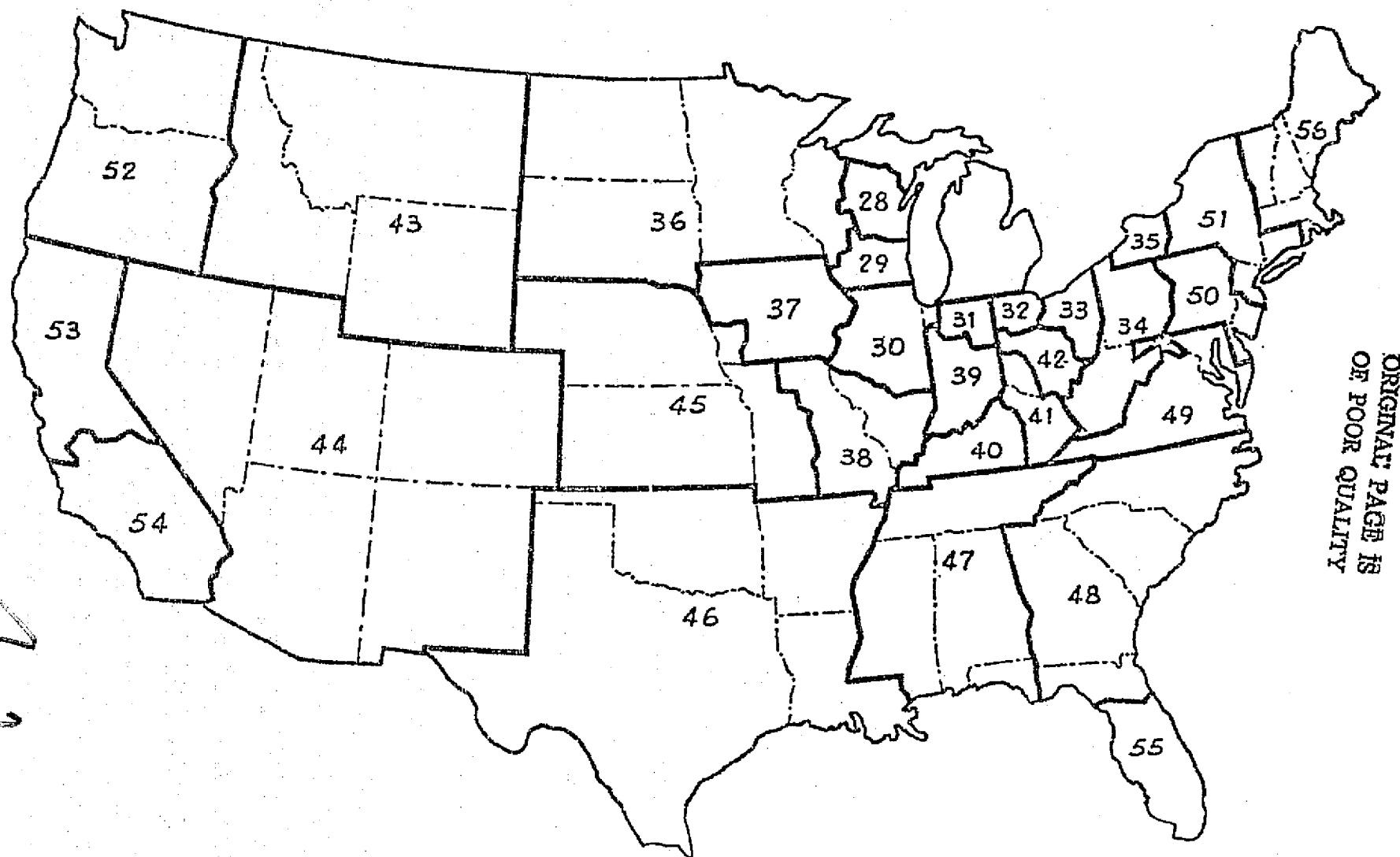


Figure 6(b) Michigan Travel Zones, Michigan State
Airport System Study Plan.



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Figure 6(c) U. S. Travel Zones, Michigan State Airport System Study Plan

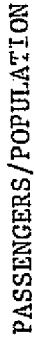


Figure 7(a) Regression Lines of Passenger Enplanements
versus Population Characteristics

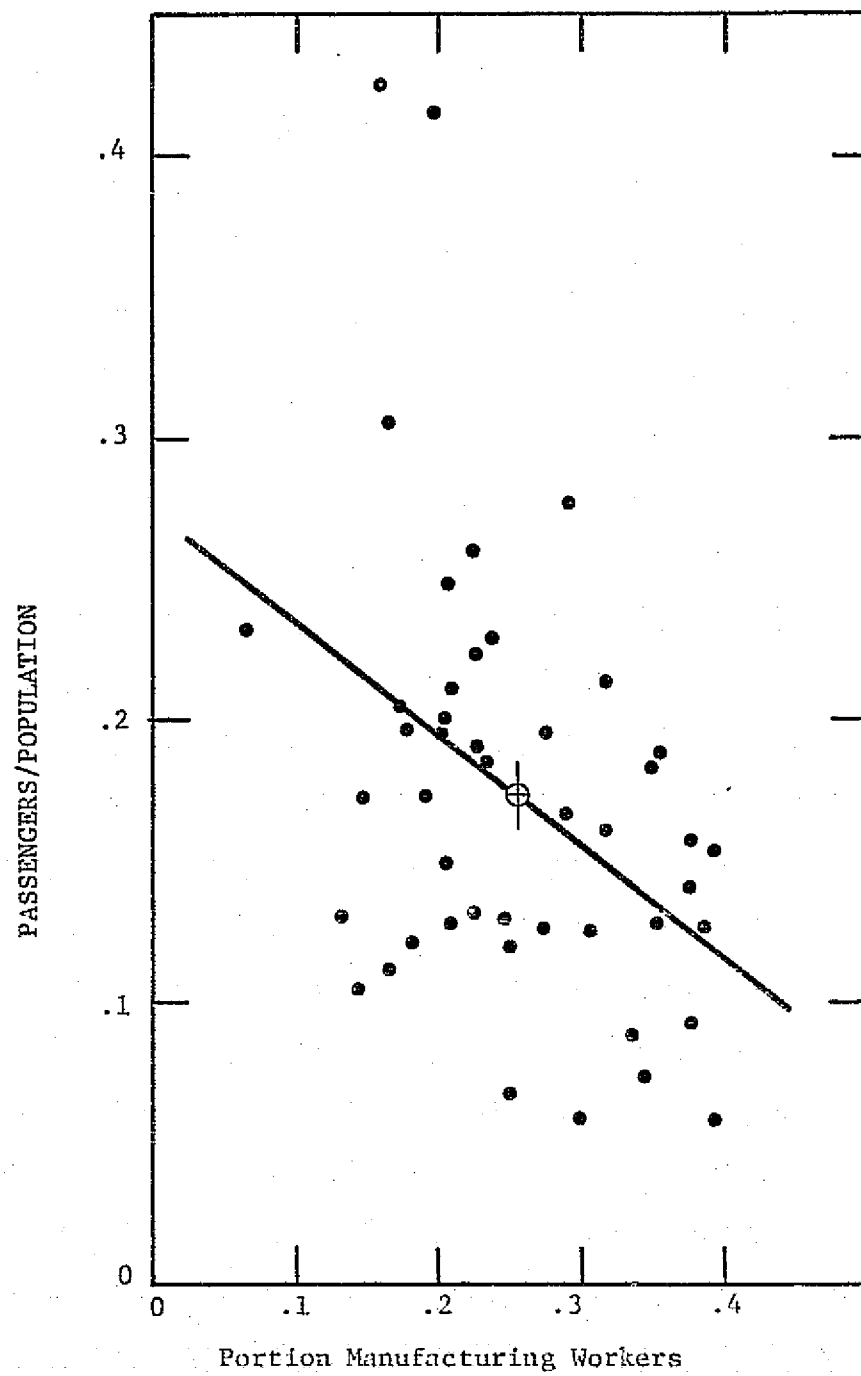


Figure 7(b)

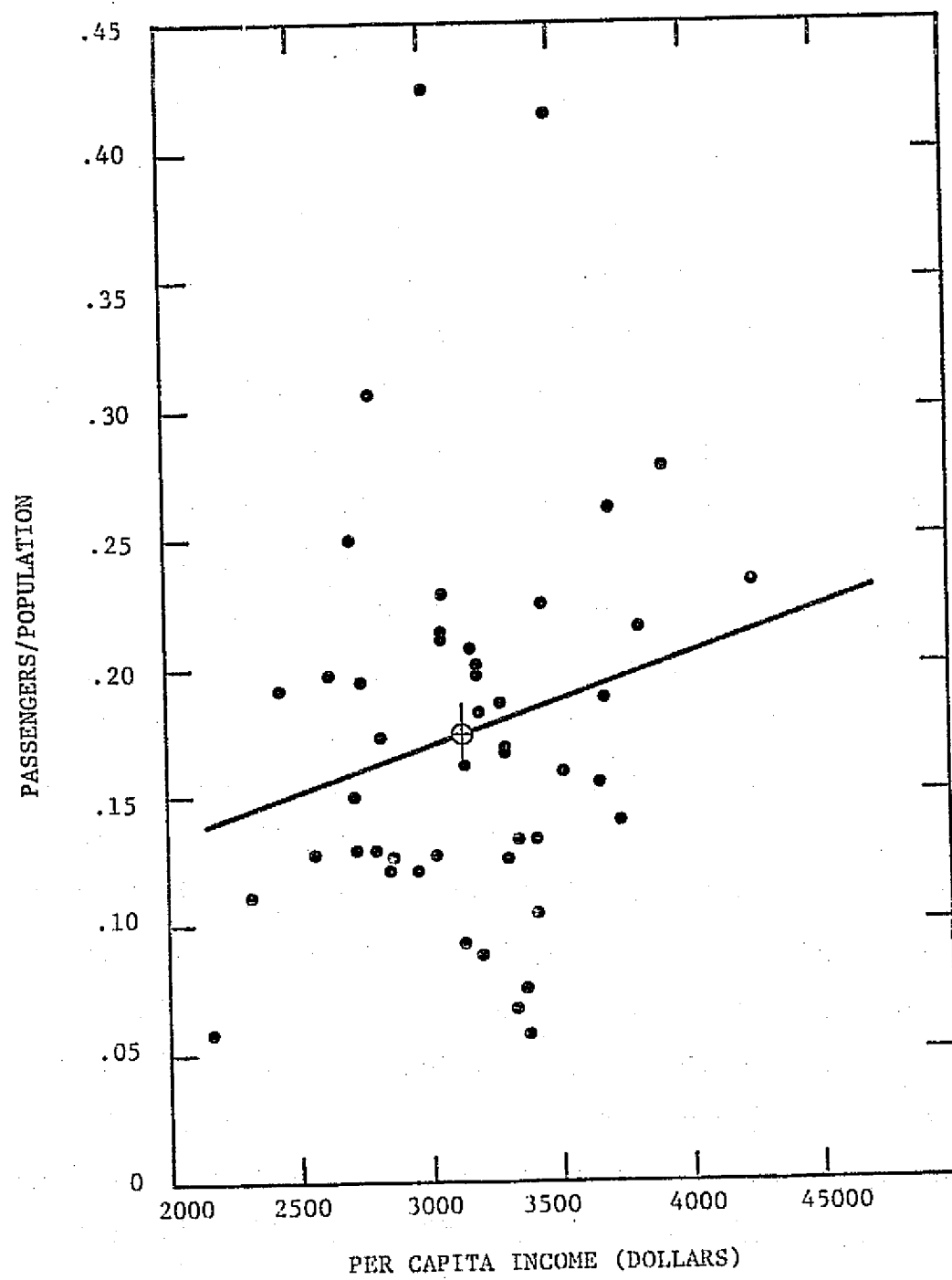


Figure 7(c)

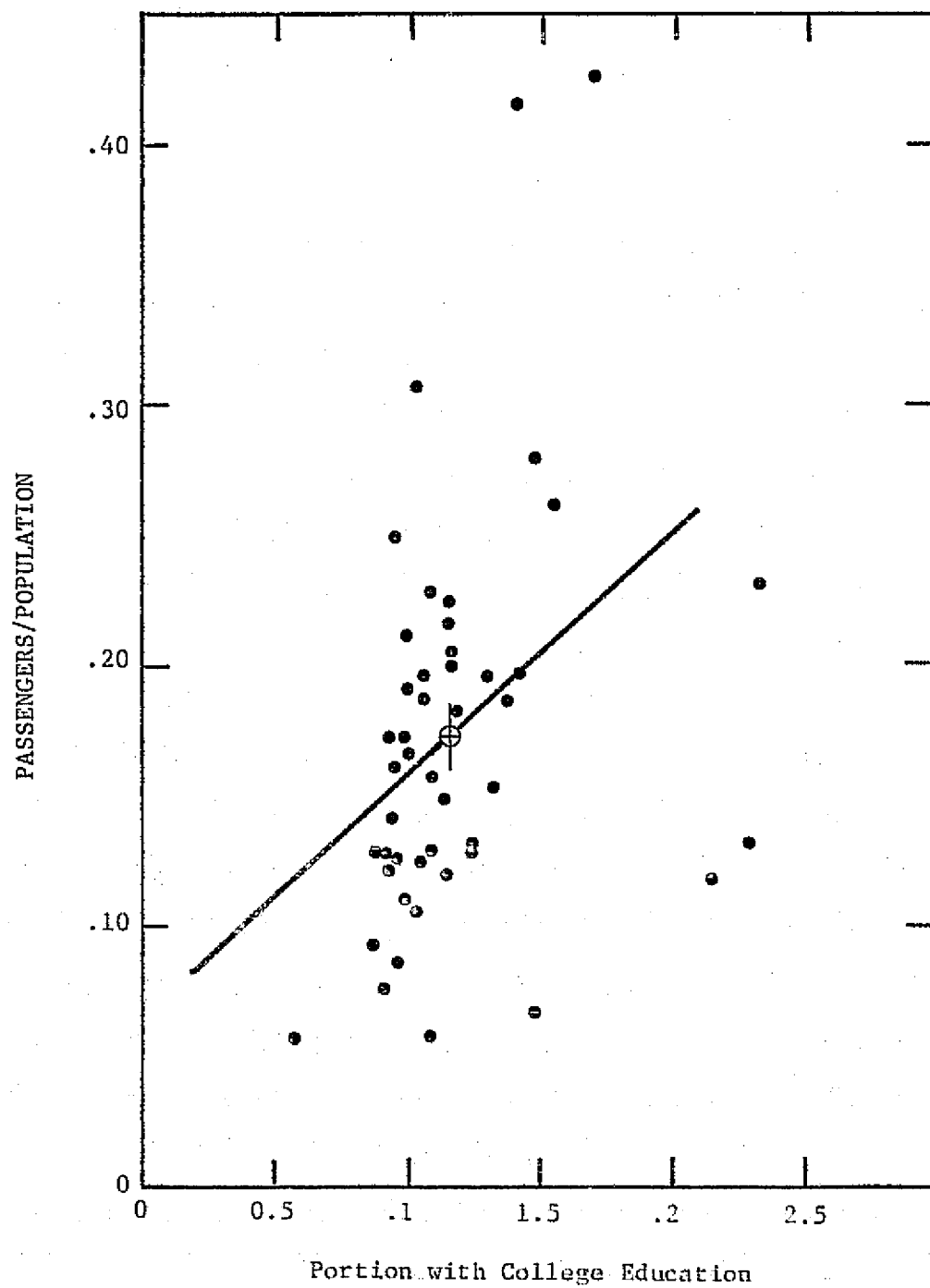


Figure 7(d)

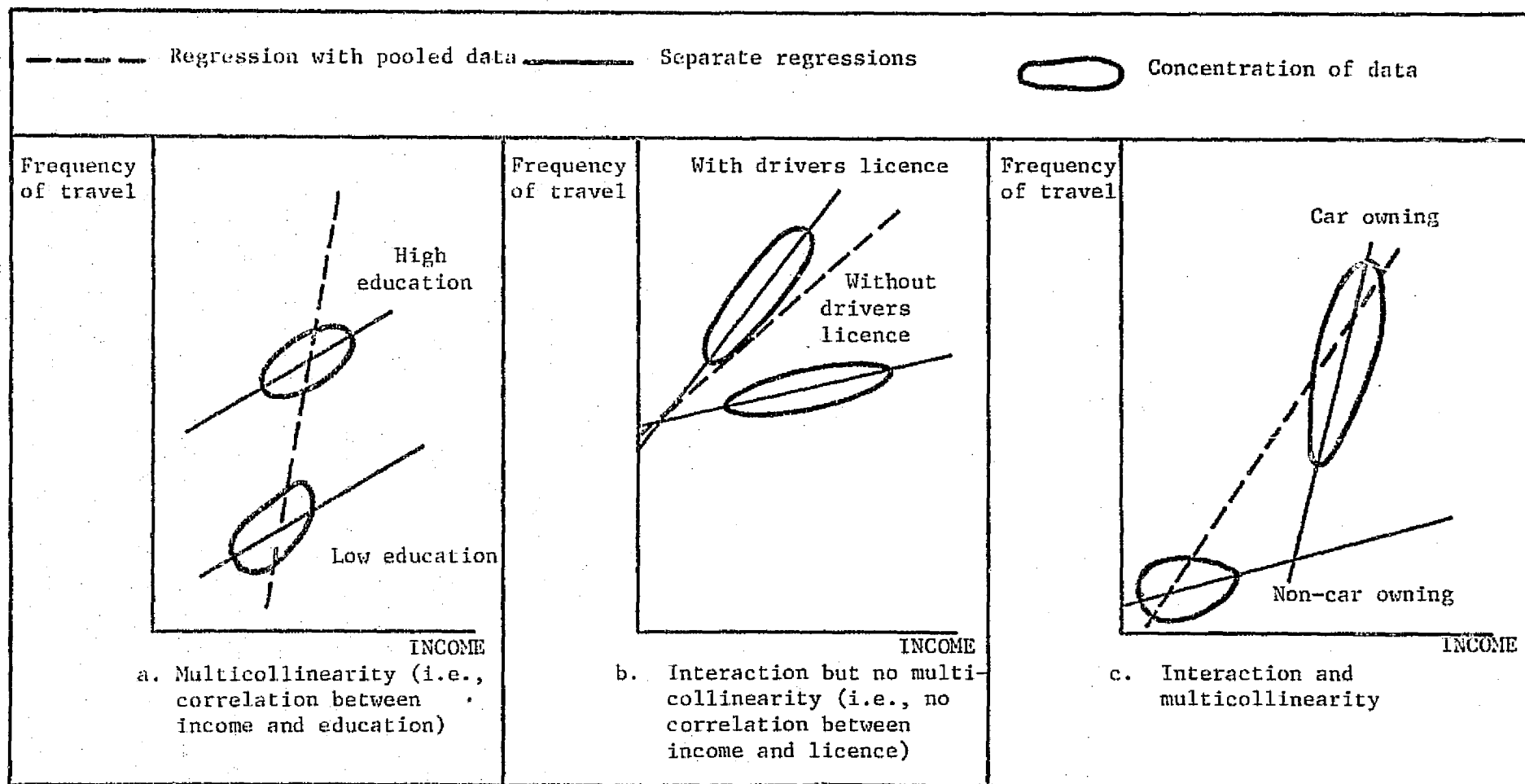
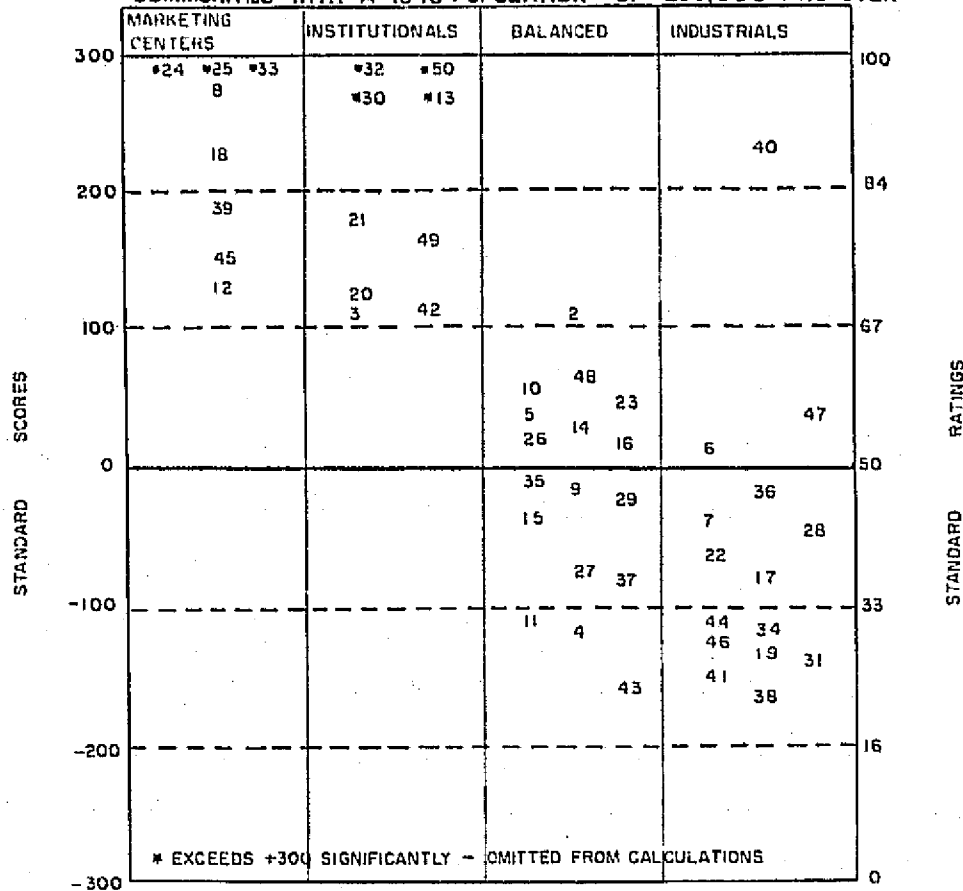


Figure 8 Interaction and Intercorrelation (from Hensher, 1976)

Figure 9

ENPLANED AIRLINE PASSENGERS PER 10,000 POPULATION
JULY - SEPTEMBER 1947

COMMUNITIES WITH A 1940 POPULATION OF 250,000 AND OVER



METROPOLITAN DISTRICT KEY							
NO	NAME	NO	NAME	NO	NAME	NO	NAME
1	NEW YORK	14	BUFFALO	26	LOUISVILLE	39	MEMPHIS
2	CHICAGO	15	MILWAUKEE	27	ALBANY-SCHEN-TROY	40	NORFOLK-PORTSMOUTH
3	LOS ANGELES	16	CINCINNATI	28	ROCHESTER NY	41	ALLENTOWN-BETHLEHEM
4	PHILADELPHIA	17	PROVIDENCE	29	BIRMINGHAM	42	SAN ANTONIO
5	BOSTON	18	KANSAS CITY	30	PORTLAND	43	NEW HAVEN
6	DETROIT	19	SCRANTON	31	SPRINGFIELD-HOLYOKE	44	WORCESTER
7	PITTSBURGH	20	NEW ORLEANS	32	DENVER	45	OMAHA
8	SAN FRANCISCO	21	HOUSTON	33	DALLAS	46	FALL RIVER
9	ST LOUIS	22	HARTFORD	34	YOUNGSTOWN	47	JAYTON
10	CLEVELAND	23	INDIANAPOLIS	35	COLUMBUS OHIO	48	SYRACUSE
11	BALTIMORE	24	SEATTLE	36	AKRON	49	SAN DIEGO
12	MINNEAPOLIS	25	ATLANTA	37	TOLEDO	50	MIAMI
13	WASHINGTON, D.C.			38	LOWELL-LAWRENCE		

The Standard score, obtained by dividing the deviation from the mean by the standard deviation in any one series ($z = \frac{x - \bar{x}}{s}$) is a useful statistical device for measuring the position of an item and comparing it with all other items. Standard scores can be converted to numerical ratings. For example, in a score rating in which 50 is the average, the standard score is divided by 5 (signum) and the resulting figures subtracted or added to 50 (depending on whether the standard score is minus or plus).

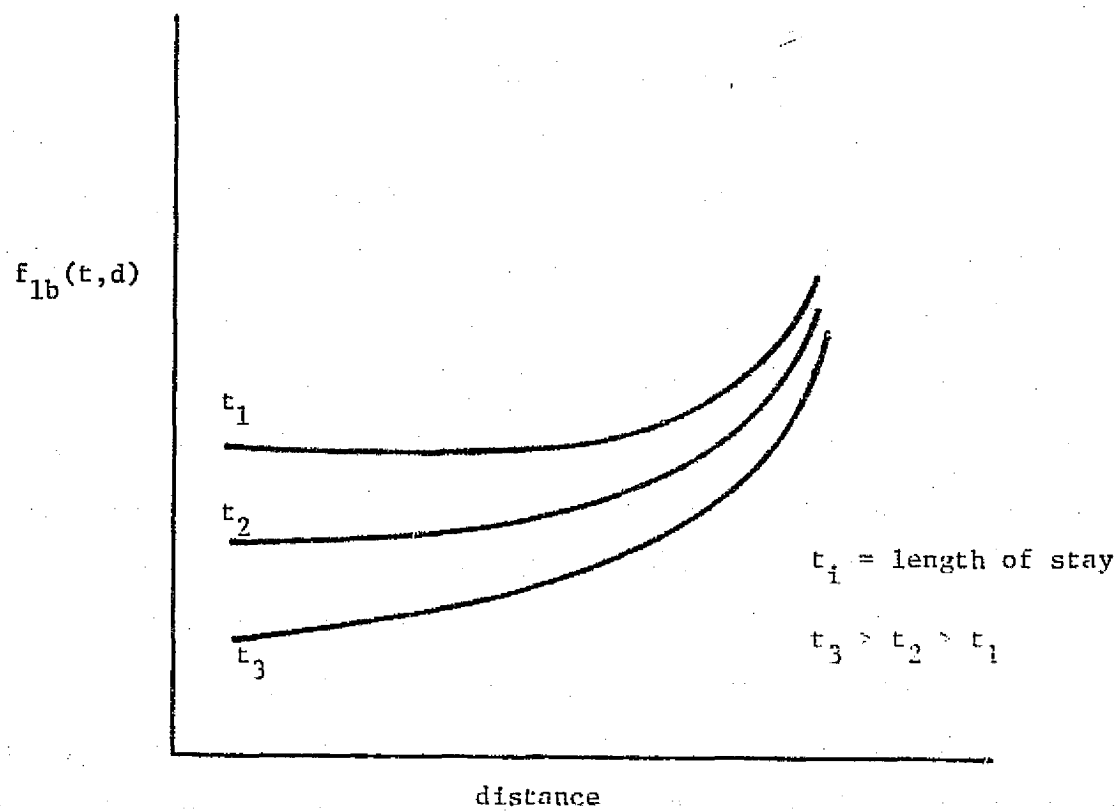


Figure 10 Conceptual Behavior of Gravity Modifier f_{lb}

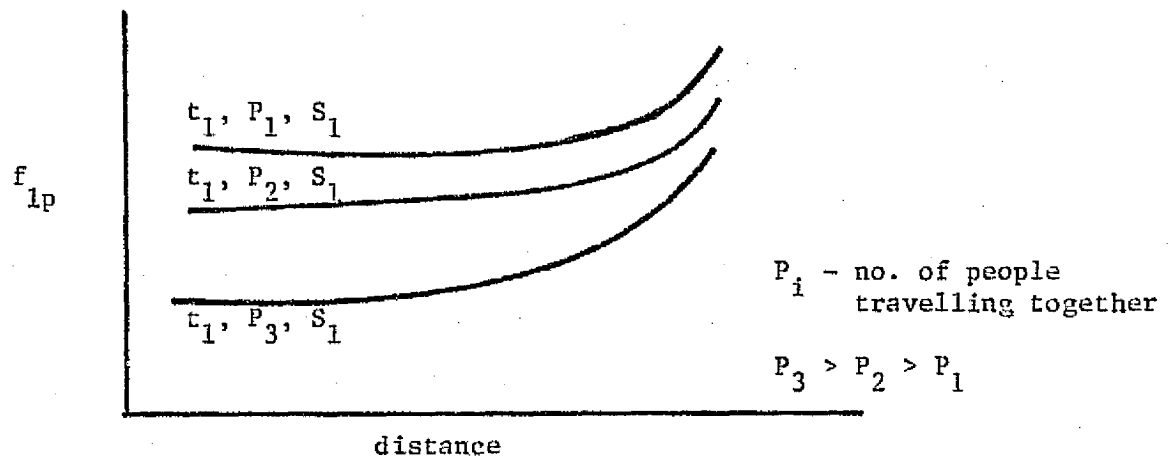


Figure 11 Conceptual Behavior of Gravity Modifier f_{lp} as a Function of Number of People Travelling Together

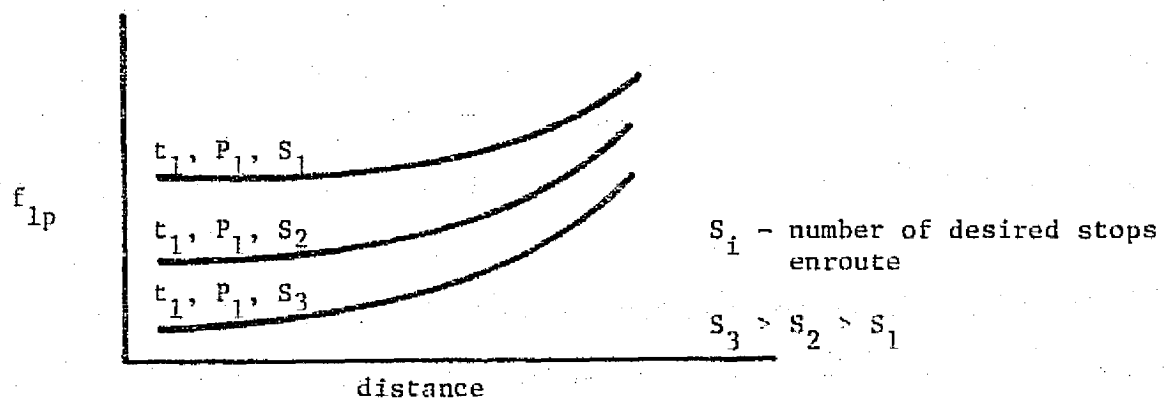


Figure 12 Conceptual Behavior of Gravity Modifier f_{lp} as a Function of Number of Desired Stops Enroute

APPENDIX A
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APPENDIX B

REVIEW OF DEMAND MODELING TECHNIQUES

A review of some techniques presently used or proposed for the purpose of determining the demand for passenger air travel is presented.

There are two approaches for demand modeling, aggregate and disaggregate. Aggregate models consider a group of individuals such as total population, labor force, and so forth. For modeling purposes, these market segments are also geographically located and aggregated by traffic zone. Disaggregate models consider an individual or a group of individuals. The grouping might be according to attributes, to socioeconomic strata, or to some other, probably nongeographic, attributes. An individual, accordingly, may become part of different population subgroups for different purposes. Demand models can be classified as

- o Aggregate models
 - o Direct demand models
 - o Disaggregate models
- o Disaggregate models
 - o Direct demand models
 - o Sequential models

Direct Demand Models: (Aggregate)

Direct-demand models estimate travel demand by origin, destination, and mode with a single equation. Direct-demand models can be specified as either modal-abstract models or modal-specific

models. The primary advantage of a modal-abstract model is that only 1 equation is necessary to estimate travel demand. This is particularly advantageous when one is estimating demands for new modes that are not in operation or for which there are no existing prototypes. The primary disadvantage associated with developing a modal-abstract model, however, is that it requires that each alternative mode be described by a single set of variables. The selection of a set of attributes that can effectively represent the wide range of system features characterizing different modes can present a major problem because homogenizing attributes means the loss of model responsiveness to policy changes.

(1) Aggregate model (direct): total enplanements of a region based upon system and/or regional attributes.

Such a demand model is used to determine the total number of people who enplane flights in a given region. This model can be generally described in the following form:

$$E_i = K x_1^{\alpha_1} x_2^{\alpha_2} \dots x_n^{\alpha_n} \quad (B1)$$

where E_i = predicted enplanements at region i .

K = calibration constant

x_1, x_2 = attributes of system and/or region (e.g., income, population, airfare, etc.)

$\alpha_1, \alpha_2, \dots, \alpha_n$ = weights

The weights and calibration constants for Eq. (B1) are generally determined by use of linear regression. Real data for enplanements and the system/regional variables can be collected over a number

of years and/or for a number of airports in a particular region (e.g., a state). Writing this equation in linear form by taking logarithms of both sides of the equation:

$$\ln E_i = \ln K + \alpha_1 \ln x_1 + \alpha_2 \ln x_2 + \dots + \alpha_n \ln x_n \quad (B2)$$

allows the use of the least squares curve-fitting technique (i.e., regression analysis) to determine values for K and the α 's (SPSS, 1976).

(2) Aggregate model (direct): enplanements between two regions based upon system and/or regional attributes.

The number of people who use air travel between two particular regions can be described in the following manner:

$$E_{ij} = K x_{1i}^{\alpha_{1i}} x_{1j}^{\alpha_{1j}} x_{2i}^{\alpha_{2i}} x_{2j}^{\alpha_{2j}} \dots x_{ni}^{\alpha_{ni}} x_{nj}^{\alpha_{nj}} x_1^{\alpha_1} x_2^{\alpha_2} \dots x_K^{\alpha_K} \quad (B3)$$

where E_{ij} = predicted enplanements between region i and region j.

K = calibration constant

$x_{1i}, x_{2i}, \dots, x_{ni}$ = attributes of region i (e.g., population, type of region, etc.)

$x_{1j}, x_{2j}, \dots, x_{nj}$ = attributed of region j.

$x_1, x_2, \dots, x_n$ = attributes of system (e.g., cost, speed, ect.)

$\alpha_{1i}, \alpha_{2i}, \alpha_{2j}, \dots, \alpha_1, \alpha_2$ = weights

Eq. (B3) is similar to Eq. (B1) in form, but it used for a different purpose. Eq. (B3) is used in order to forecast the demand for travel over a particular route (from some region i to some other region j), whereas Eq. (B1) can only be used to forecast the total number of people who will leave from region i on air trips, without any knowledge of destination. Notice that Eq. (B3)

can be used to gain the same result as Eq. (B1); that is, forecast the total enplanements at region i by summing over all destinations j as:

$$E_i = \sum_j E_{ij} \quad (B4)$$

Knowledge of demand from region i to all destination regions j makes possible a forecast of total enplanements at region i.

(3) Aggregate model (sequential): modal split between two regions based upon system attributes.

Modal split is a term used to define the percentage of travel which is conducted on a particular mode m when there are two or more competing modes of travel (e.g., air, auto, bus, rail, etc.). A modal split model for mode m forecasts the percentage of total travel between two regions which will be carried by mode m:

$$M_{mij} = \frac{\alpha_{m1} \alpha_{m2} \dots \alpha_{mn}}{\sum_m \alpha_{m1} \alpha_{m2} \dots \alpha_{mn}} \quad (B5)$$

where M_{mij} = predicted percentage for mode m of total travel conducted between region i and region j.

$x_{m1}, x_{m2}, \dots, x_{mn}$ = attributes of mode m (cost, speed, frequency of service, etc.).

$\alpha_{m1}, \alpha_{m2}, \dots, \alpha_{mn}$ = weights

Eq. (B5) is a ratio for the system attributes of mode m to the sum of the system attributes of all modes. Notice that Eq. (B5) follows directly from Eq. (B3). Equation (B3) predicts travel

between region pair i and j for the air mode, but could also be used to predict travel by other modes by using the values of the system attributes of the appropriate mode. A modal split equation is thus developed by taking the ratio of Eq. (B3) for the mode m desired to the sum of Eq. (B3) for all modes:

$$M_{mij} = \frac{T_{mij}}{\sum_m T_{mij}} = \frac{K x_{1i}^{\alpha_{1i}} x_{1j}^{\alpha_{1j}} x_{2i}^{\alpha_{2i}} \dots x_{ni}^{\alpha_{ni}} x_{nj}^{\alpha_{nj}} x_{m1}^{\alpha_{m1}} x_{m2}^{\alpha_{m2}} \dots x_{mk}^{\alpha_{mk}}}{\sum_m K x_{1i}^{\alpha_{1i}} x_{1j}^{\alpha_{1j}} x_{2i}^{\alpha_{2i}} \dots x_{ni}^{\alpha_{ni}} x_{nj}^{\alpha_{nj}} x_{m1}^{\alpha_{m1}} x_{m2}^{\alpha_{m2}} \dots x_{mk}^{\alpha_{mk}}} \quad (B6)$$

where T_{mij} = predicted travel by mode m between region i and region j.

K = calibration constant

$x_{1i}, x_{2i}, \dots, x_{ni}$ = attributes of region i.

$x_{1j}, x_{2j}, \dots, x_{nj}$ = attributes of region j.

$x_{m1}, x_{m2}, \dots, x_{mk}$ = attributes of mode m.

$\alpha_{1i}, \alpha_{1j}, \dots, \alpha_{m1}, \alpha_{m2}$ = weights

Cancelling out common terms in the numerator and denominator,

Eq. (B6) yields Eq. (B3):

$$M_{mij} = \frac{T_{mij}}{\sum_m T_{mij}} = \frac{x_{m1}^{\alpha_{m1}} x_{m2}^{\alpha_{m2}} \dots x_{mk}^{\alpha_{mk}}}{\sum_m x_{m1}^{\alpha_{m1}} x_{m2}^{\alpha_{m2}} \dots x_{mk}^{\alpha_{mk}}} \quad (B7)$$

(4) Aggregate model (direct): total enplanements of a region based upon the market share of a larger region.

A market share model is used to forecast the total enplanements at region i by expression these enplanements as a percentage of

the total enplanements of a larger region:

$$E_i = (P_i/r)E_r \quad (B8)$$

where E_i = predicted enplanements at region i.

(P_i/r) = percentage market share for region i of the total enplanements of a larger region r.

E_r = total enplanements in region r.

Eq. (B8) can be modified to express enplanements at region i in terms of market shares of more than one larger region r.

$$E_i = P_{i/r_1} P_{r_1/r_2} \dots P_{r_{m-1}/r_m} E_{r_m} \quad (B9)$$

An example of such a procedure would be the following: the enplanements at a particular metropolitan area i could be expressed in terms of a percentage market share of some region r, of the state in which region i is located. In a similar manner, the enplanements at region r_1 can be expressed as a percentage market share of the state total, and the state total can be expressed as a percentage market share of the national total.

The market shares are developed by examining the historical trend of the region i percentage of the total enplanements of region r. From this historical trend analysis, a market share for some future year is predicted, and used as shown in Eq. (B8) and (B9). Intuitively, the market share model is the simplest of the models which have been discussed here.

(5) Disaggregate deterministic model (direct): travel by mode between two regions based upon system and/or regional attributes.

A good example of disaggregation is the study of travel by purpose of trip as done by Yu, 1970 (e.g., business or pleasure), and is expressed in equation form as:

$$T_{mij}^b = K^b x_{1i}^{\alpha_{1i}} x_{ij}^{\alpha_{ij}} x_{2i}^{\alpha_{2i}} \dots x_{ni}^{\alpha_{ni}} x_{nj}^{\alpha_{nj}} x_{m1}^{\alpha_{m1}} x_{m2}^{\alpha_{m2}} \dots x_{mk}^{\alpha_{mk}} \quad (B10)$$

where T_{mij}^b = predicted travel by mode m between region i and region j for business purposes.

K^b = calibration constant

$x_{1i}, x_{2i}, \dots, x_{ni}$ = attributes of region i which are important to business travel.

$x_{1j}, x_{2j}, \dots, x_{nj}$ = attributes of region j which are important to business travel.

$x_{m1}, x_{m2}, \dots, x_{mk}$ = attributes of mode m which are important to business travel.

$\alpha_{1i}, \alpha_{ij}, \alpha_{2i}, \alpha_{2j}, \alpha_{m1}, \alpha_{m2}$ = weights

$$T_{mij}^p = K^p y_{1i}^{\beta_{1i}} y_{ij}^{\beta_{ij}} y_{2i}^{\beta_{2i}} y_{2j}^{\beta_{2j}} \dots y_{ni}^{\beta_{ni}} y_{nj}^{\beta_{nj}} y_{m1}^{\beta_{m1}} y_{m2}^{\beta_{m2}} \dots y_{mk}^{\beta_{mk}} \quad (B11)$$

where T_{mij}^p = predicted travel by mode m between region i and region j for pleasure purposes

K^p = calibration constant

$y_{1i}, y_{2i}, \dots, y_{ni}$ = attributes of region i which are important to pleasure travel.

$y_{1j}, y_{2j}, \dots, y_{nj}$ = attributes of region j which are important to pleasure travel.

$Y_{m1}, Y_{m2}, \dots, Y_{mk}$ = attributes of mode m which are important to pleasure travel.

$\beta_{1i}, \beta_{ij}, \beta_{2i}, \beta_{2j}, \dots, \beta_{m1}, \beta_{m2}$ = weights-

Eqs. (B10) and (B11) are similar in form to Eq. (B3) which is an aggregate model for mode m (assumed to be air) based upon attributes of the regions and the system (i.e., the mode). Ideally, the sum of Eqs. (B10) and (B11) should yield the same value as Eq. (B3). Disaggregation by purpose of trip is only one example of division of the traveling public according to trip and/or personal characteristics. A few other examples of disaggregation of the traveling public would be by age, income, occupation, length of stay, etc.

(6) Disaggregate deterministic model (sequential): modal split between two regions based upon system and regional factors.

A model of this type has been proposed by Jacobson and Kuhlthau, 1972 and would be written as shown below:

$$M_{mij} = f_1 \frac{\alpha_{1m} \alpha_{2m} \dots \alpha_{nm}}{\sum_m \alpha_{1m} \alpha_{2m} \dots \alpha_{nm}} + f_2 \frac{\beta_{1m} \beta_{2m} \dots \beta_{nm}}{\sum_m \beta_{1m} \beta_{2m} \dots \beta_{nm}} + \dots + f_k \frac{P_{1m} P_{2m} \dots P_{nm}}{\sum_m P_{1m} P_{2m} \dots P_{nm}} \quad (B12)$$

where M_{mij} = predicted percentage for mode m of total travel conducted between region i and region j .

$f_1, f_2, \dots, f_k$ = functions of trip characteristics (e.g., purpose of trip, length of stay, etc.)

$x_m, y_m, \dots, z_m$ = attributes of mode m.

$\beta_m, \beta_m, \dots, p_m$ = weights

System attributes to be considered are of several basic groups:

(1) a safety dimension (including reliability); (2) a cost benefit dimension, which includes time savings and convenience; (3) a comfort dimension, which includes on-board service, appearance, etc.; and (4) an in-flight dimension, which characterizes a traveler's freedom and ability to perform tasks such as reading, writing, thinking, viewing, etc.

(7) Disaggregate probabilistic model (sequential): probability that an individual will choose a certain mode of travel between two points.

Disaggregate probabilistic models have been proposed by Stopher and Meyburg, 1976 to predict the probability of an individual of a certain socioeconomic group choosing a particular mode m for the commutation trip to work. This model has not been proposed for forecasting air travel, but it is possible for it to be used as an air demand model. In addition to being disaggregate and probabilistic, the Stopher-Meyburg model is behavioral, which means the attitudes and behavior of individuals have been taken into account through study of the economics of consumer behavior and the psychology of choice behavior.

The disaggregate, behavioral, probabilistic model proposed by Stopher and Meyburg is shown below:

$$P_m^i = \frac{\exp \{U(x_m, S_i)\}}{\sum_m \exp \{U(x_m, S_i)\}} \quad (B13)$$

where P_m^i = probability that individual i will choose mode m for commuter trip.

$U(x_m, S_i)$ = common utility of mode m for individual i with socioeconomic characteristics S_i .

Eq. (B13) is referred to in the literature as a multiple-logit model. The utility assigned to a particular mode is an economic (monetary) value as perceived by the individual, depending upon his socioeconomic class. Eq. (B13) is considered disaggregate in the sense that the basic unit of observation is the individual, but can also be considered aggregate in the sense that a single set of parameters are sought to describe each socioeconomic group of the population. Basically, Eq. (B13) can be considered a probabilistic modal split model with disaggregation along the lines of socioeconomic groups in the population.